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Enhancing Paddy Yields with Advanced Nitrogen Fertilizers: A Study of Neem-coated Urea, Agrotain Urea and Nano Nitrogen

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To evaluate and compare the performance of nano nitrogen, agrotain urea, and neem-coated urea in improving nitrogen use efficiency (NUE), crop yield, and sustainability in *kharif* (Vanakalam) and *rabi* (Yasangi) rice crops in the Southern Telangana Zone of India.

Study Design: A field experiment was conducted in a randomized block design with 11 treatments and three replications to assess the effects of various nitrogen sources and application on rice productivity.

Place and Duration of Study: The field study was planned from 2021 to 2023 at Institute of Soil Health Management, Agricultural Research Institute, PJTSAU, Rajendranagar, Hyderabad, from 2021 to 2023.

Methodology: The experiment included treatments with varying nitrogen levels applied through nano nitrogen, agrotain urea, and neem-coated urea, including 100% Recommended Dose of Nitrogen (RDN), STCR (Soil Test Crop Response) based nitrogen, and reduced nitrogen doses (50% and 33% RDN). Dry matter yield at tillering, panicle initiation and harvest stages, grain and straw yield were measured at key growth stages (tillering, panicle initiation, and harvest) of rice crop.

Results: In the k*harif* season, the highest dry matter yield at panicle initiation was recorded with 100% RDN using STCR based neem coated urea (7007 kg ha^{-1}), followed by agrotain urea (6199 kg ha^{-1}) and Neem coated urea (6019 kg ha^{-1}). Nano-ntrogen sprays with reduced nitrogen doses (50% and 33% RDN) showed significantly lower yields, with 50% RDN-STCR-based NCU yielding 5826 kg ha^{-1} and 33% RDN-STCR-based NCU yielding 4899 kg ha^{-1}. In the *rabi* season, grain yields were highest with 100% RDN from STCR based N-NCU (7382 kg ha^{-1}), Agrotain urea (6741 kg ha^{-1}) and NCU (6561 kg ha^{-1}), while reduced nitrogen doses resulted in lower yields, ranging from 5886 kg ha^{-1} (50% RDN) to 5142 kg ha^{-1} (33% RDN) with STCR based N-NCU. Straw yield during *kharif* was highest with 100% RDN treatments (6540–7422 kg ha^{-1}), with reduced nitrogen doses and Nano-N sprays resulting in lower yields. The system straw yield showed the highest values with 100% RDN-STCR-based NCU (16277 kg ha^{-1}), followed by agrotain urea (14888 kg ha^{-1}) and NCU (14284 kg ha^{-1}). Nano-N sprays alone produced a system straw yield of 8119 kg ha^{-1}, higher than the control (7732 kg ha^{-1}), but significantly lower than 100% nitrogen treatments.

Conclusion: Full nitrogen applications (100% RDN) through innovative fertilizers like agrotain urea, and neem coated urea resulted in significantly higher crop yields and nutrient uptake compared to reduced nitrogen doses. The study highlights the critical role of adequate nitrogen in improving nitrogen use efficiency and sustaining rice production systems, with substantial yield gains observed at 100% RDN (up to 44% for grain yield and 37% for straw yield).

Keywords: Grain yield; straw yield; dry matter production; STCR; nano nitrogen spray.

1. INTRODUCTION

Rice (*Oryza sativa) is* a staple food crop that sustains more than half of the global population, particularly in Asia, where it is a major source of nutrition and livelihood. The productivity of rice is highly dependent on the availability of essential nutrients particularly nitrogen, which plays a crucial role in promoting vegetative growth, enhancing tillering, and improving grain formation (Zhang et al., 2023). However, the effective use of nitrogen fertilizers is a complex challenge due to issues such as nutrient losses, environmental pollution, and inefficiency in traditional nitrogen application methods (Mustafa et al., 2022 and Sui et al*.,* 2013).

In India, since most of the urea is applied as surface broadcasting, there is a significant loss of N as ammonia volatilization as a result of rapid hydrolysis. Since, the hydrolysis of urea is catalyzed by urease enzyme, its regulation can help in reducing the volatilization losses and hence improving NUE (Govindasamy et al*.,* 2024). Agrotain urea (N-butyl thiophosphoric triamide) is one of the products, which inhibits urease activity, helps to improve the nitrogen use efficiency in rice, maize, wheat and other crops in India. NH3 volatilization from untreated urea (2.6% of applied N) exceeded urea + NBPT(AGR) (0.2%) throughout the 20-day study at the University of Arkansas Rice Research and Extension Center. (Rogers et al., 2015).

In recent years, advanced nitrogen fertilizers have been developed to address these challenges and improve nutrient use efficiency in rice cultivation. Among these, neem-coated urea

(NCU)**,** agrotain urea, and nano nitrogen (Nano-N) have gained significant attention for their potential to enhance nitrogen retention, reduce volatilization, and provide a more sustained release of nutrients during critical growth stages (Verma et al., 2023, Adhikari et al., 2019). Neem-coated urea and agrotain urea are slow-release fertilizers that aim to minimize nitrogen losses, while Nano**-**N, a novel technology is designed to optimize nitrogen uptake through foliar applications.

So, it is important to know the performance of innovative fertilizers, which can increase crop yield, quality, use efficiency, saving of N and sustainability of agricultural systems. By keeping this back ground the present investigation was initiated with the following objectives of evaluating the improvement in the yields to know the comparative performance of nano nitrogen, agrotain urea and neem coated urea in *kharif* (Vanakalam) and *rabi* (Yasangi) rice crops of Southern Telangana Zone.

2. MATERIALS AND METHODS

A field experiment was carried out at Institute of Soil Health Management, Agricultural Research Institute, PJTAU, Rajendranagar, Hyderabad during 2021-23 employed in a randomized block design with 11 treatments and three replications. The farm is geographically located at 17° 19' 29.21" North Latitude and 78° 23' 48.59" East Longitude. The soil was sandy loam in texture with 16% clay; 32% silt and 52% sand with a pH of 7.75 and EC of 0.831 dSm^{-1}, available nitrogen of 165 kg ha^{-1} (low), available P_2O_5 of 66 kg ha^{-1} (high) and available K_2O of 299 kg ha^{-1} (medium).The experiment consists of eleven treatments in rice crop *i.e.,* T_1-100% RDN-NCU (1/3rd-B + 1/3rd-MT + 1/3rd-PI, T_2 -1/3rd of 100% RDN-NCU-B +1NS-MT+1NS-PI, T_3- 50% RDN-NCU -3 splits+1NS-MT+1NS-PI, T_4 - 100%RDN-Agrotain UG -1/3rd-B+1/3rd-MT+1/3rd-PI, T_5 -1/3rd of 100% RDN Agrotain UG-B+1NS-MT+1NS-PI, T_6-50% RDN- Agrotain UG-3 splits+1NS-MT+1NS-PI, T_7 -100% STCR based N-NCU-1/3rd-B+1/3rd-MT+1/3rd- PI, T_8 - 1/3rd of 100% N on STCR based-NCU+1NS equivalent to 1/3rd STCR based N-MT+1NS equivalent to 1/3rd STCR based N-PI , T_9-50% STCR based N-NCU - 3 splits+1NS-MT+1NS-PI, T_{10} -3 NS - 15 DAT, MT & PI, T_{11}- Control (No N). The treatments aimed to evaluate the impact of reduced nitrogen rates combined with nano N sprays applied @1250 ml ha^{-1} on nutrient uptake and crop performance. RDN is 120-60-40 kg per ha^{-1} for kharif and 150-60-40 for rabi season. Soil samples from the 0–15 cm depth were collected to assess baseline fertility and guide nitrogen application. Fertilizer application followed the recommended doses for *Kharif*, with nitrogen applied in three splits and phosphorus in two splits and potassium as basal. Grain and straw were recorded at harvest, dry matter production at maximum tillering, panicle initiation stages were recorded using standard method. The data obtained from the experimental trial in respect of various observations were statistically analyzed following the analysis of variance technique for randomized block design as suggested by Gomez & Gomez, (1984). For, dry matter production, five destructive samples were collected from each plot, they were shade dried, cut into pieces and then dried in hot air oven at 65°C by keeping them in brown paper bags. The weight was recorded and expressed in kg ha^{-1}. Grain yield was recorded by harvesting plants from plot area and dried in the field upto 14% moisture, threshed seperately and weighed, expressed in kg ha^{-1}. Meanwhile straw yield was recorded after threshing and expressed in kg ha^{-1}.

3. RESULTS AND DISCUSSION

Dry Matter Yield: The *kharif* mean dry matter production of rice was significantly influenced by nitrogen (Table 1). Nano-N applied as three sprays without additional nitrogen recorded lower dry matter yields at maximum tillering (964 kg ha^{-1}) and panicle initiation (3324 kg ha^{-1}) comparable to the control without nitrogen application (922 and 3136 kg ha^{-1}, respectively). In contrast, nitrogen applied at 100% RDN through NCU, STCR-based N, or agrotain UG resulted in the highest dry matter yields ranging from 1530–1738 kg ha^{-1} at tillering and 6019–7007 kg ha^{-1} at panicle initiation. These findings align with Babu et al., (2013) and Meena et al*.,* (2019).

Reduced nitrogen doses (50% and 33% RDN) supplemented with two nano-N sprays did not match the yields of 100% RDN treatments. Application of urea as foliar spray along with Zinc was reported to increase dry matter production by Tuimong et al*.,* (2022).

At 50% RDN, STCR-based N with nano-N sprays produced 1498 kg ha^{-1} at tillering and 5826 kg ha^{-1} at panicle initiation, while agrotain U

Table 1. Effect of different levels of Nano nitrogen, Agrotain and Neem coated urea on dry matter yield (kg ha^{-1}) of rice at maximum tillering and panicle initiation stages during *kharif,* 2021 and 2022

Trt. No	Treatments	Maximum tillering			Panicle initiation		
		2021	2022	Pooled mean	2021	2022	Pooled mean
T_1	Control (No N)	903	940	922	3064	3208	3136
T_2	3 Nano-N sprays (15DAT, MT&PI)	950	978	964	3281	3367	3324
T_3	100% RDN-NCU	1498	1563	1530	5880	6157	6019
T_4	100% RDN- STCR based N-NCU	1688	1789	1738	6788	7226	7007
T_5	100% RDN- Agrotain UG	1534	1584	1559	6091	6308	6199
T_6	50% RDN-NCU+2 Nano N sprays	1261	1314	1287	4726	4947	4836
T_7	50% RDN-STCR based N-NCU+2 Nano N sprays	1414	1582	1498	5468	6184	5826
T_8	50% RDN-Agrotain UG + 2 Nano sprays	1274	1321	1297	4824	5025	4925
T_9	33% RDN-NCU+2 Nano N sprays	1105	1120	1113	3923	3985	3954
T_{10}	33% RDN-STCR based N-NCU+2 Nano N sprays	1221	1405	1313	4518	5280	4899
T_{11}	33% RDN-Agrotain UG +2 Nano N sprays	1100	1121	1111	3960	4043	4002
	Mean	1268	1338	1303	4775	5066	4921
	SEm±	38	44	44	166	176	113
	CD@0.05%	111	128	129	489	581	333

*Note: *100% and 50% RDN -3 equal splits (1/3rd basal,1/3rd MT&1/3rd PI) and 33% RDN as basal *2 Nano N sprays: 1 NS at maximum tillering and 1 NS at panicle initiation stage* recorded 1297 and 4925 kg ha⁻¹, respectively. At 33% RDN, basal STCR-based N with nano-N sprays yielded 1313 kg ha⁻¹ at tillering and 4899 kg ha⁻¹ at panicle initiation, highlighting a progressive decline with reduced nitrogen levels.

Nitrogen significantly influenced the *rabi* dry matter yield of rice at maximum tillering and panicle initiation stages (Table 2). The lowest yields were recorded with nano-N applied as three sprays without additional nitrogen comparable to the nitrogen-free control (1073 vs. 1058 kg ha⁻¹ at tillering). In contrast, the highest yields were achieved with 100% RDN using STCR-based urea, agrotain urea or NCU ranging from 1750 to 1944 kg ha⁻¹ at tillering and 6835 to 8152 kg ha⁻¹ at panicle initiation, with STCR-based urea recording the maximum yield (8152 kg ha⁻¹). These findings align with Mondal et al., (2020). Positive correlation of yield with nitrogen applied was reported by Ghajbhiye et al., (2024) and Mahajan et al., (2012).

Reducing nitrogen levels to 50% or 33% RDN supplemented with two nano-N sprays resulted in significantly lower yields compared to 100% RDN treatments, underscoring the importance of adequate nitrogen. At 50% RDN, agrotain urea recorded 1517 and 5600 kg ha⁻¹, while STCR-based nitrogen with nano-N sprays yielded 1626 kg ha⁻¹ at tillering and 6259 kg ha⁻¹ at panicle initiation. A marked decline was observed at 33% RDN, where STCR-based nitrogen with nano-N sprays produced 1363 kg ha⁻¹ at tillering and 5221 kg ha⁻¹ at panicle initiation. These results does not match with findings by Midde et al., (2022) that 50% urea combined with 50% Nano urea improves grain and straw yield. Additionally, the superior performance of agrotain urea over regular urea supports the observations of Liu et al., (2019).

Among the two seasons dry matter production was low at the initial stages and increased till the panicle initiation stage which might be due to the increase in the demand for nitrogen for preceeding stages. This was reported by Payman et al., (2017) and Uddin et al., (2024). These results emphasize that maintaining adequate nitrogen levels is critical for optimal biomass production. While nano-N sprays can partially supplement nitrogen, they cannot fully compensate for significant reductions in nitrogen application. The consistency in yields across seasons indicates minimal seasonal impact on dry matter production.

In the *rabi* season, grain yields were statistically affected by nitrogen (Table 3). Nano-N sprays alone yielded 3883 kg ha⁻¹, comparable to the control (3684 kg ha⁻¹). Recommended nitrogen doses (100% RDN) applied via STCR-computed N, NCU, or agrotain urea produced the highest yields (6561–7382 kg ha⁻¹), with STCR-computed N outperforming agrotain urea and NCU, though the difference between NCU and agrotain urea was non-significant. Reduced nitrogen levels (50% and 33% RDN) with nano-N sprays resulted in significantly lower yields, ranging from 5588–5886 kg ha⁻¹ at 50% RDN and 5040–5142 kg ha⁻¹ at 33% RDN. These findings contrast with Lahari et al. (2021), emphasizing the need for adequate nitrogen. STCR-based N application increased yields by 12.5, 5.3 and 2.0% at 100, 50, and 33% RDN compared to NCU. agrotain urea improved yields by 9.5, 2.8, and 0.8% over NCU at the same RDN levels. Yield gains between 33% and 50% RDN were 11% (NCU), 14% (STCR-based NCU), and 12% (agrotain urea). Increasing nitrogen from 33% to 100% RDN improved yields by 30–44%, depending on the source. Ramulu et al., (2019), Gangadevi et al., (2012) and Maheswari et al., (2007) also reported the improved yields with increase in nitrogen content.

Nano-N sprays increased yields by 5% over the control but were significantly outperformed by 100% RDN treatments, which enhanced yields by 69% (NCU), 90% (STCR-based NCU), and 74% (agrotain urea). System grain yields mirrored this trend. Nano-N sprays (7137 kg ha⁻¹) showed non-significant differences from the control (6768 kg ha⁻¹). The highest system yield (13570 kg ha⁻¹) was recorded with 100% RDN-STCR-based urea, followed by Agrotain-UG (12407 kg ha⁻¹). Reduced nitrogen levels (50% and 33% RDN) with nano-N sprays yielded 10238–10875 kg ha⁻¹ and 9181–9575 kg ha⁻¹, respectively. Similar yield declines with reduced nitrogen were reported by Mrudhula & Suneetha, (2020) and Maurya et al., (2021), reinforcing the importance of full nitrogen applications for optimal rice productivity.

The straw yield of rice during *kharif* (2021 and 2022) and *rabi* (2021-22 and 2022-23) as well as the system straw yield across both seasons, was significantly influenced by nitrogen (Table 4). Nano-N sprays alone, applied as three sprays without additional nitrogen, recorded straw yields ranging from 3702 to 4417 kg ha⁻¹, similar to

Table 2. Effect of different levels of nano nitrogen, agrotain and neem coated urea on dry matter yield (kg ha^{-1}) of rice at maximum tillering and panicle initiation stages during *rabi,* 2021-22 and 2022-23

Trt. No	Treatments	Maximum tillering			Panicle initiation		
		2021-22	**2022-23**	**Pooled mean**	**2021-22**	**2022-23**	**Pooled mean**
T_1	Control (No N)	1055	1060	1058	3358	3739	3548
T_2	3 Nano-N sprays (15DAT, MT&PI)	1068	1078	1073	3536	3908	3722
T_3	100% RDN-NCU	1697	1803	1750	6520	7150	6835
T_4	100% RDN- STCR based N-NCU	1905	1983	1944	7759	8545	8152
T_5	100% RDN- Agrotain UG	1754	1849	1801	6747	7428	7087
T_6	50% RDN-NCU+2 Nano N sprays	1363	1497	1430	5302	5801	5551
T_7	50% RDN-STCR based N-NCU+2 Nano N sprays	1562	1690	1626	5975	6543	6259
T_8	50% RDN-Agrotain UG + 2 Nano sprays	1460	1574	1517	5354	5846	5600
T_9	33% RDN-NCU+2 Nano N sprays	1259	1287	1273	4360	4811	4586
T_{10}	33% RDN-STCR based N-NCU+2 Nano N sprays	1349	1376	1363	4970	5472	5221
T_{11}	33% RDN-Agrotain UG +2 Nano N sprays	1268	1307	1287	4411	4907	4659
	Mean	1431	1500	1466	5299	5832	5565
	SEm±	29	34	42	185	190	159
	CD@0.05%	125	113	123	546	561	468

*Note: *100% and 50% RDN -3 equal splits (1/3rd basal,1/3rd MT&1/3rd PI) and 33% RDN as basal *2 Nano N sprays: 1 NS at maximum tillering and 1 NS at panicle initiation stage*

Table 3. Effect of different levels of nano nitrogen, agrotain and neem coated urea on grain yield (kg ha^{-1}) of rice during *kharif,* 2021-22 and *rabi*, 2021-23

Trt. No	Treatments	*Kharif*			*Rabi*			System grain yield		
		2021	**2022**	**Pooled mean**	**2021-22**	**2022-23**	**Pooled mean**	**2021-22**	**2022-23**	**Pooled mean**
T_1	Control (No N)	3023	3145	3084	3516	3853	3684	6539	6998	6768
T_2	3 Nano-N sprays (15DAT, MT&PI)	3190	3318	3254	3729	4037	3883	6919	7355	7137
T_3	100% RDN-NCU	5388	5695	5542	6353	6770	6561	11741	12465	12103
T_4	100% RDN- STCR based N-NCU	5968	6408	6188	7120	7644	7382	13088	14052	13570
T_5	100% RDN- Agrotain UG	5578	5753	5666	6504	6979	6741	12082	12732	12407
T_6	50% RDN-NCU+2 Nano N sprays	4529	4773	4651	5413	5763	5588	9942	10535	10238
T_7	50% RDN-STCR based N-NCU+2 Nano N sprays	4905	5073	4989	5701	6072	5886	10605	11146	10875
T_8	50% RDN-Agrotain UG + 2 Nano sprays	4625	4829	4727	5560	5896	5728	10184	10725	10455

Trt. No	Treatments	*Kharif*			*Rabi*			System grain yield		
		2021	2022	Pooled mean	2021-22	2022-23	Pooled mean	2021-22	2022-23	Pooled mean
T_9	33% RDN-NCU+2 Nano N sprays	4065	4216	4141	4840	5241	5040	8904	9457	9181
T_{10}	33% RDN-STCR based N-NCU+2 Nano N sprays	4288	4577	4433	4946	5338	5142	9234	9916	9575
T_{11}	33% RDN-Agrotain UG +2 Nano N sprays	4104	4288	4196	4865	5334	5099	8969	9622	9295
	Mean	4515	4734	4624	5322	5721	5521	9837	10455	10146
	SEm±	143.82	147.11	142.92	167.96	177.88	170.87	255.958	255.589	253.28
	CD@0.05%	424.19	433.91	421.56	495.41	524.66	503.98	760.393	759.296	752.437

*Note: *100% and 50% RDN -3 equal splits (1/3rd basal,1/3rd MT&1/3rd PI) and 33% RDN as basal*
**2 Nano N sprays: 1 NS at maximum tillering and 1 NS at panicle initiation stag*

Table 4. Effect of different levels of nano nitrogen, agrotain and neem coated urea on straw yield (kg ha^{-1}) of rice during *kharif,* 2021-2022 and *rabi,* 2021-23

Trt. No	Treatments	*Kharif*			*Rabi*			System straw yield		
		2021	2022	Pooled mean	2021-22	2022-23	Pooled mean	2021-22	2022-23	Pooled mean
T_1	Control (No N)	3320	3596	3458	4101	4446	4274	7421	8042	7732
T_2	3 Nano-N sprays (15DAT, MT&PI)	3547	3856	3702	4238	4597	4417	7785	8453	8119
T_3	100% RDN-NCU	6226	6854	6540	7370	8118	7744	13596	14972	14284
T_4	100% RDN- STCR based N-NCU	7053	7791	7422	8412	9297	8855	15465	17089	16277
T_5	100% RDN- Agrotain UG	6464	7134	6799	7695	8483	8089	14159	15618	14888
T_6	50% RDN-NCU+2 Nano N sprays	4909	5376	5143	5899	6459	6179	10808	11835	11322
T_7	50% RDN-STCR based N-NCU+2 Nano N sprays	5515	6059	5787	6509	7146	6828	12024	13206	12615
T_8	50% RDN-Agrotain UG + 2 Nano sprays	5007	5487	5247	5914	6482	6198	10922	11969	11445
T_9	33% RDN-NCU+2 Nano N sprays	3830	4164	3997	4644	5055	4849	8474	9218	8846
T_{10}	33% RDN-STCR based N-NCU+2 Nano N sprays	4420	4826	4623	5335	5823	5579	9755	10649	10202
T_{11}	33% RDN-Agrotain UG +2 Nano N sprays	3902	4290	4096	4727	5156	4942	8630	9446	9038
Mean		4927	5403	5165	5895	6460	6178	10822	11863	11343
SEm±		166	182	174	200	224	212	291	276	283
CD@0.05%		492	534	515	590	662	626	865	821	837

*Note: *100% and 50% RDN -3 equal splits (1/3rd basal,1/3rd MT&1/3rd PI) and 33% RDN as basal*
**2 Nano N sprays: 1 NS at maximum tillering and 1 NS at panicle initiation stage*

the control treatment (3458–4274 kg ha⁻¹), indicating limited efficacy when used without supplementary nitrogen. The highest straw yields were achieved with the recommended nitrogen dose (100% RDN) applied through STCR-based NCU, Agrotain Urea, or NCU, ranging from 6540 to 7422 kg ha^{-1} during *kharif* and 7744 to 8855 kg ha^{-1} during *rabi*. Among these treatments, STCR-based NCU consistently produced the highest straw yields, with a 13.4% increase over NCU and 9.2% over agrotain urea during *kharif*. During *rabi*, STCR-based NCU was 10.5% and 9.5% higher than NCU and agrotain urea, respectively. The differences between NCU and agrotain urea were non-significant at 100% RDN, showing similar performance at full application rates.

Reduced nitrogen doses (50% and 33% RDN) with nano-N sprays resulted in significantly lower straw yields compared to 100% RDN treatments. Yields for these treatments ranged from 6179 to 6828 kg ha^{-1} at 50% RDN and 4849 to 5579 kg ha^{-1} at 33% RDN during *Rabi*, with similar reductions observed in *Kharif*. Straw yields under 33% RDN-STCR-based NCU increased by 15.7% and 12.9% over NCU and agrotain urea, respectively, and by 10.5% and 10.2% at 50% RDN. Compared to Nano-N sprays alone, 33% RDN treatments improved straw yields by 10–26%, and 50% RDN treatments resulted in improvements of 40–55%. These findings align with reported by Zaidi & Tripathi, (2007), Khalil et al., (2019), Kandil et al., (2013), and Anushka et al., (2023).

The system straw yield, combining both kharif and rabi seasons, was significantly affected by nitrogen levels and sources. The highest system straw yield was recorded with 100% RDN-STCR-based NCU (16277 kg ha^{-1}), followed by agrotain urea (14888 kg ha^{-1}) and NCU (14284 kg ha^{-1}). These findings of system yield were also reported by Pasha et al. (2018). Nano-N sprays alone resulted in a system straw yield of 8119 kg ha^{-1}, slightly higher than the control (7732 kg ha^{-1}) but the difference was non-significant. Reduced nitrogen levels, even with nano-N sprays, resulted in significantly lower system straw yields, ranging from 11322 to 12615 kg ha^{-1} at 50% RDN and 8846 to 10202 kg ha^{-1} at 33% RDN. Reductions were most pronounced when nitrogen was decreased from 100% to 33% RDN, with reductions of 37, 37, and 39% observed for NCU, STCR-based NCU, and agrotain urea, respectively, emphasizing the need for full nitrogen application for maximizing straw yields. Islam et al., (2010) demonstrated that reductions in nitrogen dosages resulted in decreased yield (Sahu et al., 2022).

4. CONCLUSION

In conclusion, nitrogen levels from different sources played a crucial role in determining the yield and straw production of rice across both kharif and rabi seasons. Full nitrogen application at the recommended dose (100% RDN), particularly through STCR-based NCU, agrotain urea, and NCU, resulted in the highest straw yields and grain production. The performance of STCR-based NCU was consistently superior, leading to significant yield improvements over other nitrogen sources, particularly during the kharif and rabi seasons. In contrast, Nano-N sprays alone, without additional nitrogen, showed limited efficacy, with yields similar to the control treatments. Reduced nitrogen levels (50 and 33% RDN), even with nano-N supplementation, resulted in significantly lower yields, underscoring the importance of adequate nitrogen supply for optimal rice growth. The results reinforce that precise nitrogen management, especially using STCR-based NCU, is essential for maximizing both seasonal and system straw yields, ensuring high rice productivity.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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