International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X

www.agronomyjournals.com
2025; SP-8(2): 92-96
Received: 25-11-2024
Accepted: 29-12-2024

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Performance of wet direct-seeded rice (*Oryza sativa* L.) with different levels and sources of slow-release urea fertilizers

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DOI: https://doi.org/10.33545/2618060X.2025.v8.i2Sb.2531

Abstract
A field experiment was conducted to study the effect graded levels and sources of slow-release urea fertilizers on growth, yield, nitrogen use efficiency and economics of wet direct seeded rice in kharif, 2022. The results revealed that 100% recommended dose nitrogen at 120 kg ha^{-1} through silicon and cedar wood oil coated urea recorded highest drymatter production at all stages of crop i,e active tillering, panicle emergence, flowering and harvest respectively. Similar results of leaf area index, SPAD chlorophyll and green seeker readings were also found at 100% recommended dose of nitrogen through silicon and cedar wood oil coated urea at all stages of crop i,e active tillering, panicle emergence and flowering. The results revealed that 100% RDN (Recommended Dose of Nitrogen) (120 kg/ha) applied through silicon coated urea resulted in the highest grain yield (6183 kg/ha) and straw yield (7047 kg/ha) which ulimately fetched higher gross return of ₹. 1,37,933/ha, net returns ₹. 98,763 and benefit-cost ratio of 2.52. The data indicated that significantly higher agronomic nitrogen use efficiency (32.2 kg kg^{-1}), partial factor productivity (51.5 kg kg^{-1}) and utilization efficiency (43.0 kg kg^{-1}) were recorded in treatment receiving 100% RDN through silicon coated urea. It can be concluded that RDN applied through silicon coated urea @ 120 kg/ha found to be a suitable alternative source to neem coated urea in increasing the grain yield and profitability.

Keywords: Economics, nitrogen use efficiency, slow release urea fertilizer, wet direct seeded rice, yield

1. Introduction
Urea is the least efficient fertilizer among the ammonium containing nitrogen (N) sources. High loss and low nitrogen use efficiency demand and the factors responsible for such wastage of expensive input need to be studied. Low nitrogen use efficiency and loss of nitrogen through different ways due to its high solubility is the major loss and need to be lessen by using of slow release or controlled-release fertilizers to enhance use efficiency attempts have been made to develop slow-release or controlled-release fertilizers by reducing the rate of their dissolution. Urea is one of the most widely used sources of fertiliser N in the world. It has high nitrogen content (46%), in comparison to many other nitrogen sources. When urea is applied to soil, it undergoes hydrolysis transformed into ammoniacal (NH_4^+) form and followed by nitrite (NO_2^-) and nitrate (NO_3^-) forms by the process of nitrification. Most of the crop plants use nitrate as a source of nitrogen except rice which prefers ammoniacal form over the nitrate form. Rapid nitrification is one of the key processes that encourage nitrogen losse from the soil. This leading to reduced crop recovery.

Among the primary nutrients nitrogen (N) is crucial for achieving optimal rice yields [1]. Low nitrogen use efficiency (NUE) of rice led to excessive and ineffective use of N fertilizer, which caused serious soil degradation, ground water pollution and emission of ammonia and greenhouse gases due to surface runoff, leaching into ground water and volatilization into the atmosphere [2]. Many experimental studies have shown that slow-release urea fertilizers (SRUF) are effective in enhancing yield and NUE of rice [3] and [4].

Leaching losses of urea and nitrate nitrogen, volatilization losses of NH_3 from standing water and denitrification losses under reduced conditions are some of the losses occurred in waterlogged transplanted paddy.

Since rice requires large amount of nitrogen to reach potential yield, it is possible to increase rice production per unit area by increasing the quantity of nitrogen application or by increasing the efficiency of the applied fertilizer nitrogen. It takes about 1 kg of nitrogen to produce 15 to 20 kg of grain, but the efficiency of nitrogen use in India is very low [5]. Use efficiency of applied nitrogen is very low in rice soils and it varies from 18 to 40%. The reason for this low use efficiency can be attributed to the losses *viz*., ammonia volatilization and denitrification [6].

The applied nitrogen through the slow release fertilizer as sole or in combination in the ratio of 1:1 released the nitrogen slowly upto longer time during the crop period. This process is mainly governed by the urease enzyme and microbial process which was slower than the chemical reactions governed in soil [7]. Reducing pre-plant N fertilizer and increasing the number of split applications had a greater advantage on increasing yield than increase in the amount of N applied [8].

Additionally, N fertilizer is becoming expensive because of increasing demand for fossil fuels worldwide. Therefore, exploring effective measures to reduce nutrient losses from farmland, while maintaining crop yield has become a priority for the sustainable development of agriculture, particularly for rice production to not only favor the profitability but also to reduce the negative environmental impacts. Several researchers have tested different N management practices to improve N use efficiency [9], [10] and [11]. Recently, the use of controlled release N fertilizer has been found to be an effective way to increase the NUE and reduce N losses from paddy fields [11]. Moreover, a reduction in the level of N fertilizer supplied and amount of irrigation is the most effective measure to control nitrate leaching in cropland farming [12] and [13]. In addition, optimized fertilization could increase the NUE of rice [14] and reduce the N and phosphorous (P) losses from source [15]. However, the effects of N-saving methods vary depending on different environmental conditions. Keeping in view the low nitrogen use efficiency, it has been felt to find out the use of some indigenous use of material and coating process for reducing the nitrogen losses from urea.

At high doses, the N use efficiency may be low besides leading to other ill effects of lodging and susceptibility to pests and diseases particularly blast disease. These effects could be minimized with the use of silicon, so application of silicon is found to improve N use efficiency besides imparting resistance to pests and diseases. In this context, slow release urea fertilizers such as silicon coated urea and cedar wood oil coated urea are developed at ICAR-IIRR laboratory were tested in wet direct seeded rice under field condition.

Hence, the present investigation was conducted to study Performance of wet direct-seeded rice (*Oryza sativa* L.) with different levels and sources of slow-release urea fertilizers on growth, yield, nitrogen use efficiency and Economics.

2. Materials and Methods

The field experiment was conducted at the research farm ICAR-Indian Institute of Rice Research (ICAR-IIRR) Rajendranagar geographically situated at an altitude of 542.3 m above the mean sea level and located at 17°19' N latitude and 78°23' E longitude. It represents the Southern Telangana agro-climatic zone of Telangana state. According to Troll's climatic classification, it falls under semi-arid tropics (SAT). The soil of the experimental site was clay loam in texture, slightly alkaline in nature, medium in organic carbon, medium in soil available nitrogen (251.3 kg ha^{-1}), medium in available phosphorus (34.9 kg ha^{-1}) and potassium (325.5 kg ha^{-1}). The experiment was laid out in a Randomized block design with ten treatments consist of nitrogen management practices were allocated randomly and replicated thrice. Popular short duration rice variety DRR Dhan-55 with 120 days duration was selected for the study. Good quality seed of cultivar DRR Dhan-55 @ 25 kg ha^{-1} was soaked for 24 hours and incubated in moist gunny bag for 24 hours. The sprouted seed was sown by manual dibbling method on a well-prepared field. As per the treatments inorganic fertilizers *viz*., urea, single super phosphate and muriate of potash were used to supply nutrients to plants. The recommended fertilizer dose of 120:60:40 kg N: P_2O_5: K_2O ha^{-1} was applied. Full dose of phosphorus and potassium were applied as basal dose as per treatments. Nitrogen was applied in splits as per the treatments in each plot. Silicon and cedar wood oil coated urea is a type of controlled-release fertilizer that combines urea, a commonly used nitrogen fertilizer, with a silicon and cedar wood oil coating. By coating urea granules with a layer of silicon and cedar wood oil, the release of nitrogen is controlled, reducing the potential for nutrient loss and improving the efficiency of fertilizer use. Dose of silicon and cedar wood oil coated slow release urea (60, 90, 120 and 150 kg N ha^{-1}, respectively) were applied as per the treatment. It was prepared in the lab by mixing the normal urea with silicon (which is obtained from rice husk) and cedar wood oil. Complete dose of urea coated fertilizers were applied in three equal splits. Weeds in the experimental field were managed by two hand weedings at critical period of crop weed competition i.e. 15 and 45 DAT to keep the field weed free. Bispyribac sodium herbicide was applied at 2-3 leaf stage of weeds at 15 DAT of rice crop. Rice crop requires more quantity of water for its growth and survival. At the time of sowing a thin film (2-3 cm) of water was maintained for better establishment of seedlings. A depth of 5 ± 2 cm water level was maintained during the entire crop period except at the time of top dressing of fertilizers. From panicle initiation stage to 21 days after flowering, ± 5 cm depth of water was maintained. Last irrigation was provided at seven to ten days before physiological maturity stage of the crop. To control seed borne diseases, the seed was treated with carbendazim (50% WP) @ 4g kg^{-1} of seed. Mixture of fipronil (5% SC) @1ml litre^{-1} and carbendazim (50% WP) @ 1g litre^{-1} of water was sprayed at 45 DAS for stem borer and blast management, respectively. The **c**rop was harvested when grain and straw color changed from green to straw yellow colour. Harvesting was carried out manually with the help of sickles leaving about 5 to 10 cm stubbles in the field. At first border plants were harvested and removed from the plot and then net plot plants were harvested. The soil samples were collected with help of spade, crow bar from each net plot in the experimental field. The collected samples were allowed to dry in the shade for few days and subjected to grinding process to obtain 0.2 mm sieve soil particles to carry out the chemical analysis. Soil chemical analysis was carried out by using standard procedures. Economics of crop establishment methods and nitrogen management in rice was calculated based on prevailing market rates. For computing the cost of cultivation, different variable cost items were considered. The cost includes expenditure on seed, organic manures, chemical fertilizers, plant protection chemicals and labour charges at prevailing market prices. Gross returns were calculated by multiplying grain and straw yield with their respective prevailing price of paddy in the market. The net returns hectare^{-1} were calculated by subtracting the cost of cultivation from the gross returns and presented as ₹. ha^{-1}. The Benefit-cost ratio for all the treatments was worked out by dividing cost of cultivation to net returns. The level of significance used in 'F' and 't' test was at 5% probability. Wherever 'F' test was found significant, the 't' test was used to estimate critical differences among various treatments.

3. Results and Discussion

At active tillering stage, the highest dry matter production of rice crop (5820 kg ha^{-1}) was observed in the plots applied with 100% RDN through silicon coated urea, however, on par with 100% RDN (120 kg N ha^{-1}) through cedar wood oil coated urea (5759 kg ha^{-1}) and 100% RDN (120 kg N ha^{-1}) through neem coated urea (5740 kg ha^{-1}). Similar trend was also observed at further stages of the crop. The highest dry matter (18223 kg/ha) at harvest was recorded in the plots applied with 100 percent RDN through Si-CU at harvest stage of crop which was on a par with 100 percent RDN @120 kg N ha^{-1} through CWOCU (17691 kg/ha) and 100 percent RDN through NCU (17065 kg/ha). The lowest dry matter production was observed in control plots. Dry matter production is an important gateway to achieve higher yield. Similar findings were also observed by [16].

At active tillering, panicle emergence and flowering stage the highest leaf area index (3.8, 6.6 and 8.2) was recorded in the plots applied with 100% RDN through silicon coated urea which is on par with cedar wood oil coated urea (3.8, 6.4 and 8.2) and 100% RDN through neem coated urea (3.8, 6.2 and 8.2). The lowest leaf area index was recorded in the plots where nitrogen was not applied. Higher leaf area index might be ascribed due to higher number of tillers and leaf number associated with these treatments.

With regards to grain yield significantly higher yield was registerd in plots applied with 100 percent RDN @ 120 kg N ha^{-1} through silicon and cedar wood oil coated urea (6183 and 6025 kg/ha, respectively) and it was on par with 100 percent RDN through neem coated urea (5649 kg/ha) at @ 120 kg N ha^{-1}. Whereas, the lowest grain yield (2320 kg/ha) was observed with no application of nitrogen. Similar findings were also observed by [17] and [18].

Similarly, Si-CU and CWOCU @ 120 kg N ha^{-1}(7047 and 6957 kg/ha, respectively) resulted in the highest straw yield that might be due to sufficient nitrogen availability during the crop growth phase, which resulted in enhanced dry matter output and found at par with NCU @ 120 kg N ha^{-1} (6507 kg/ha). The lowest straw yield was recorded in control plot (2842 kg/ha). The other possible reason in yield enhancement might be due to continuous and steady supply of N into the soil by coated fertilizers to meet the required nutrient for physiological processes, which in turn improved grain yield [19]. Unlike grain and straw, harvest index of different treatments did not differ significantly. This might be due to negligible difference in the ratio of economics to biological yield among the treatments.

Table 1: Performance of wet direct-seeded rice (*Oryza sativa* L.) with different levels and sources of slow-release urea fertilizers

Treatments	Dry matter (kg ha^{-1})				Leaf Area Index			Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
	AT	PE	F	HT	AT	PE	F		
T_1	5740	12947	14880	17065	3.8	6.2	8.2	5649	6507
T_2	3449	7432	8701	10058	2.1	4.0	4.8	3163	3881
T_3	4226	8980	10559	12549	2.6	4.8	6.0	4092	4930
T_4	5820	13768	16134	18223	3.8	6.6	8.2	6183	7047
T_5	5091	10889	13112	14678	3.3	5.5	7.2	5548	6401
T_6	3439	6502	8599	9822	1.9	3.7	4.8	3094	3752
T_7	4195	8777	10452	12304	2.5	4.6	5.9	3975	4571
T_8	5759	13200	15220	17691	3.8	6.4	8.2	6025	6957
T_9	4904	10496	12723	14618	3.2	5.4	7.0	5436	6391
T_{10}	2988	5397	6926	7877	1.5	3.1	3.8	2320	2842
SE(m)±	208	342	513	566	0.11	0.18	0.25	210	197
CD(p=0.05)	618	1016	1524	1683	0.33	0.55	0.76	625	585

*Note AT-Active tillering; PE-Panicle emergence; F-Flowering; HT-harvest

Table 2: Effect of different levels and source of slow releasing nitrogenous fertilizers on economics of rice cultivation

Treatments		Gross Returns (₹. ha^{-1})	Net Returns (₹. ha^{-1})	B-C Ratio
T_1	NCU @120 kg N ha^{-1}	126129	87555	2.52
T_2	Si-CU@ 60 kg N ha^{-1}	70973	32826	0.91
T_3	Si-CU @ 90 kg N ha^{-1}	91690	53031	1.44
T_4	Si-CU @ 120 kg N ha^{-1}	137933	98763	2.65
T_5	Si-CU @ 150 kg N ha^{-1}	123883	84100	1.90
T_6	CWOCU @ 60 kg N ha^{-1}	69372	31273	0.87
T_7	CWOCU @ 90 kg N ha^{-1}	88741	50154	1.36
T_8	CWOCU @ 120 kg N ha^{-1}	134551	95476	2.53
T_9	CWOCU @ 150 kg N ha^{-1}	121562	81999	1.89
T_{10}	Control (No nitrogen)	52048	14926	0.44
SEm(±)		4357	4357	0.11
CD (0.05)		12945	12945	0.33

Assessment of treatments in terms of economic traits revealed that the gross return, net returns and benefit cost (B: C) ratio differed due to different slow releasing nitrogenous fetilizers. Among the different treatments, highest gross return were recorded with application of 100 percent RDN through Si-CU (Rs.137933 ha^{-1}) which is on par with 100 percent RDN applied through CWOCU (Rs.134551 ha^{-1}) and NCU (Rs.126129 ha^{-1}). Similar trend was recorded with maximum net return were obtained in the treatment 100 percent RDN through Si-CU and CWOCU (Rs. 98763 ha^{-1} and Rs. 95476 ha^{-1}) which is on par with 100 percent RDN through NCU (Rs. 87555 ha^{-1}). The higher gross and net return was mainly attributed to higher grain and straw yields. Similar findings were also observed by [20] and [21].

Table 3: Nitrogen use efficiency of wet direct seeded rice as influenced by different levels and source of slow release urea fertilizers

Treatments		AE	PFP	PUE	UE
T_1	NCU @120 kg N ha^{-1}	27.7	47.1	52.4	35.3
T_2	Si-CU@ 60 kg N ha^{-1}	14.1	52.7	29.3	16.3
T_3	Si-CU @ 90 kg N ha^{-1}	19.7	45.1	37.9	22.2
T_4	Si-CU @ 120 kg N ha^{-1}	32.2	51.5	57.3	43.0
T_5	Si-CU @ 150 kg N ha^{-1}	21.5	37.0	51.4	22.9
T_6	CWOCU @ 60 kg N ha^{-1}	12.9	51.6	28.7	16.0
T_7	CWOCU @ 90 kg N ha^{-1}	18.4	44.2	36.8	20.2
T_8	CWOCU @ 120 kg N ha^{-1}	30.9	50.2	55.8	39.3
T_9	CWOCU @ 150 kg N ha^{-1}	20.8	36.2	50.4	22.0
T_{10}	Control (No nitrogen)	0.0	0.0	0.0	0.0
SEm(±)			2.26	2.05	4.95
CD (0.05)			6.72	6.10	14.72

Note* AE-Agronomic Efficiency; PFP-Partial factor productivity; PUE-Physiological use efficiency; UE-Utilization efficiency

The data indicated that significantly higher agronomic nitrogen use efficiency (32.2 and 30.9 kg kg^{-1}) was recorded in treatment receiving 100% RDN through silicon coated and cedar wood oil coated urea which was on par with 100% RDN through neem coated urea (27.7 kg kg^{-1}). The lowest agronomic nitrogen use efficiency was recorded in control plots with no nitrogen application are presented in Table 3.

The physiological nitrogen use efficiency (PNUE) differed significantly across the treatments. Lowest physiological nitrogen use efficiency was recorded in treatment with no application of nitrogen. From the data it is clearly evident that treatments varied their use efficiency from 0.00 to 57.3 kg kg^{-1}.

The data indicated that significantly higher partial factor productivity (51.5 and 50.2 kg kg^{-1}) was recorded in treatment receiving 100% RDN through silicon coated and cedar wood oil coated urea which was on par with 100% RDN through neem coated urea (47.1 kg kg^{-1}). The lowest partial factor productivity was recorded in control plots with no nitrogen application.

From the data on utilization efficiency it is evident that significantly higher utilization efficiency (43.0 and 39.3 kg kg^{-1}) was recorded in treatment receiving 100% RDN through silicon coated and cedar wood oil coated urea which was on par with 100% RDN through neem coated urea (35.3 kg kg^{-1}). The lowest utilization efficiency was recorded in control plots with no nitrogen application

4. Conclusion

From the results of the present study it can be concluded that silicon coated urea applied @ 120 kg ha^{-1} resulted in the highest growth, yield parameters and grain yield which was responded positively to the increasing doses (from 50% to 100% of RDN). Further the same treatment fetched high net returns and B:C ratio. Cedar wood oil coated urea @ 120 kg ha^{-1} was also found to be equal in terms in terms of grain yield and net returns. So, silicon coated urea and cedar wood oil coated urea @ 120 kg ha^{-1} may be recommended as an alternative to neem coated urea.

5. Acknowledgement

I express my sincere gratitude to the Indian Institute of Rice Research (ICAR-IIRR), Hyderabad, for their collaboration with Professor Jayashankar Telangana State Agricultural University (PJTSAU). Their support made it possible to conduct this study.

6. Competing interests

Authors have declared that no competing interests exist.

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