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Effect of Varying Levels and Source of Slow-release Urea Fertilizers on Yield, Post Harvest Soil Nutrient Status and Economics of Wet Direct Seeded Rice (*Oryza sativa L.*)

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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

A field experiment was conducted at the research farm of ICAR-Indian Institute of Rice Research (IIRR), Hyderabad, Rajendranagar in *kharif,* 2022 to study the effect of varying levels and source of slow-release urea fertilizers on yield, post harvest soil nutrient status and economics of wet direct seeded rice. The experiment was laid out in a randomized block design with ten treatments consisting of nitrogen management practices and replicated thrice. The results revealed that 100% RDN (Recommended Dose of Nitrogen) (120 kg/ha) applied through silicon coated urea resulted in the highest grain yield (6249 kg/ha) and straw yield (7114 kg/ha). Post harvest soil nutrient status

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revealed that 125% recommended dose nitrogen (150 kg/ha) applied through silicon coated urea resulted in the highest soil available nitrogen. Similarly, the highest soil available nitrogen gain was recorded in the plots that received 125% silicon coated urea. Silicon coated urea applied @ 120 kg/ha ulimately fetched higher gross return of ₹. 1,42,964/ha, net returns ₹. 1,03,793 and benefit-cost ratio of 2.65. It can be concluded that RDN applied through silicon coated urea @ 120 kg/ha found to be a suitable alternative to neem coated urea in increasing the grain yield, soil fertility and profitability.

Keywords: Wet direct seeded rice; cedar wood oil coated urea; nitrogen use efficiency; silicon coated urea.

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. There are broadly of two types: coated conventional fertilizers or inherently low solubility fertilizers. Conventional N fertilizers can be coated with pervious or semipervious substances such as sulphur, oilseed cakes, polymers or resins to control the release of nitrogen. In order to reduce N losses from the soil, various slow release fertilizers have been developed that would provide a continuous and regular supply of nitrogen during annual cycle. Among these fertilizers one of the best known is neem coated urea (NCU). The nitrification process which release nitrogen varies with the type of fertilizer material and other soil conditions. Efforts are being made to retard the nitrification process or make it slow so as to increase its efficiency. Slow release of nitrogenous fertilizers like urea mixed or coated with neem may give higher fertilizer use efficiency than urea in case of rice, maize, sugarcane and other crops. 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 [1]. 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 [2].

The use of nitrification inhibitors and slow release N fertilizers has been suggested for increasing N efficiency [3]. Improvement in grain yield and nitrogen use efficiency by using nitrification inhibitors and slow releasing nitrogenous fertilizers like granular urea, neem oil coated, tar coated, neem cake coated urea in rice have been reported by many workers [4,5].

Direct-seeded rice sowing can be categorized into three methods: (1) wet seeding (sprouted rice seeds are broadcast or sown in lines on puddled soil), (2) water seeding (seeds sown into standing water) and (3) dry seeding (dry rice seeds are broadcast or drilled in unpuddled soil. Direct seeding of rice with subsequent aerobic soil conditions avoids water requirement for puddling and maintenance of submerged soil conditions, and thus reduces the overall total water demand and different N losses can also be reduced [6].

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 [7]. 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 [8,9]. In addition, optimized fertilization could increase the NUE of rice [10] and reduce the N and phosphorous (P) losses from source [11]. However, the effects of N-saving methods vary depending on different environmental conditions. In this context, slow release urea fertilizers such as silicon coated urea and cedar wood oil coated urea are developed at ICAR-IIRR laboratory and their efficiency was need to be tested in field condition.

Hence, the present investigation was conducted to study the effect of different slow release urea fertilizers (SRUF) on yield parameters, yield, post harvest soil nutrient status and economics of wet direct seeded rice.

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 $17^{o}19'$ N latitude and $78^{o}23'$ 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, low in soil available nitrogen (251.3 kg/ha), medium in available phosphorus (34.9 kg/ha) and potassium (325.5 kg/ha). The experiment was laid out in a Randomized block design with ten treatments consisting of nitrogen management practices were allocated randomly in three replications. 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 was soaked 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. 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}) 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 was managed by hand weeding 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 $\pm$ 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, $\pm$ 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

Among the treatments at harvest stage significantly the highest plant height (101.8 cm) was recorded in the plots applied with 120 kg ha^{-1} silicon coated urea (Si-CU) which was on par with cedar wood oil coated urea (CWOCU) @

120 kg N ha^{-1} (97.8 cm) and 100 per cent recommended dose of neem coated urea (NCU) fertilizer (94.3 cm) at harvest (Table 1). Thus, all coated fertilizers conserved N which made available for growth and development of paddy at later stages also. These results were in accordance with Kumar et al. [12] and Abbasi [13].

The highest dry matter (18223 kg/ha) at harvest was recorded in the plots applied with 100 per cent RDN through Si-CU at harvest stage of crop which was on a par with 100 per cent RDN @120 kg N ha^{-1} through CWOCU (17691 kg/ha) and 100 per cent 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 Kumar et al. [12]. Significantly maximum number of productive tillers per m^{-2} (289.0) was recorded in the plots applied with 120 kg Si-CU ha^{-1} which was on par with CWOCU @ 120 kg N ha^{-1} (284.0) and NCU @ 120 kg N ha^{-1} (275.3). Reddy and Prasad (1975) showed that coating of urea with neem had nitrification inhibition effect on urea-N for a period of more than two weeks and this helped in conserving urea-N for longer time in soil in ammonium form.

Among all treatments significantly higher total number of grains per panicle (174) was noticed in the plots applied with 120 kg Si-CU ha^{-1} which was on par with CWOCU @ 120 kg N ha^{-1}(169) and 100 per cent recommended dose of NCU fertilizer (164). However panicle length, panicle weight and test weight were found to be non significant. Similar results were obtained by Maragatham et al*.* [14].

However, more availability for uptake and steady supply of nutrients might have enhanced the higher panicle length and panicle weight due to more availability of photosynthates. These results were in similar with the findings of Jeena et al*.* [15]. Increase in filled grains and test weight under different slow releasing nitrogenous fertilizers was due to N induced translocation of photosynthates and aminoacids from the active leaves and culms to the grain. This work was in accordance with the findings of Belder et al*.* [16]. Significantly higher grain yield was observed in plots applied with 100 per cent RDN @ 120 kg N ha^{-1} through silicon and cedar wood oil coated urea (6249 kg/ha and 6025 kg/ha, respectively) and it was on par with 100 per cent RDN through neem coated urea (5949 kg/ha) at @ 120 kg N ha^{-1}. Whereas, the lowest grain yield (2320 kg/ha) was observed with restricted application of nitrogen. Similar findings were also observed by Bhuiyan et al. [17] and Rao et al. [18].

Similarly, Si-CU and CWOCU @ 120 kg N ha^{-1}(7114 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} (6673kg/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.

The post-harvest soil nutrient status indicated that Si-CU @ 150 kg N ha^{-1} resulted in significantly highest post-harvest soil available nitrogen of 351.7 kg/ha and cedar wood oil coated urea @ 150 kg N ha^{-1} resulted in the highest N status of 348.3 kg/ha among the different doses which was on par with 100% RDN @120 kg N ha^{-1} neem coated urea (331.3 kg) due to inhibition of nitrification process and reduced leaching and volatilization losses (Table 2). It was slowly released and available to plants continuously. The results obtained in the present investigation were in agreement with the results of Zahir and Ahmad [20]. Further, the available nitrogen status in soil decreased with the crop growth probably because of increased uptake by crop with its maturity and other losses that took place during the crop growth period. However available P_2O_5 content and available potassium content was not differ significantly among treatments.

Initial soil status of experimental field was recorded to be medium in soil available nitrogen (251.3 kg/ha), medium in available phosphorus (34.9 kg/ha) and potassium (325.5 kg/ha). Among the nitrogen management practices, Si-CU and CWOCU @ 150 kg N ha^{-1} applied plots recorded the highest gain of soil available nitrogen (100.37 and 97.03 kg N ha^{-1}, respectively) over initial status (Fig. 1). Si-CU @ 90 kg N ha^{-1} applied plots showed negative balance of applied nitrogen (-4.97 kg/ha) due to more uptake and more N use efficiency. Apart from control plots, plots that received silicon and cedar wood oil coated slow release urea @ 60 kg N ha^{-1} recorded the highest negative balance

Table 1. Effect of different levels and source of slow release urea fertilizers on growth, yield attributes and yield of wet direct seeded rice

Treatments		Plant height at harvest (cm)	Dry matter at harvest (kg/ha)	Number of productive tillers m^{-2}	Panicle length (cm)	Panicle weight (g)	Total no. of grains $panicle^{-1}$	1000 grain weight(g)	Grain yield (kg/ha)	Straw yield (kg/ha)	HI (%)
T_1	NCU @120 kg N ha^{-1}	94.3	17065	275.3	23.0	4.4	164	24.5	5949	6673	47.1
T_2	Si-CU@ 60 kg N ha^{-1}	55.2	10058	169.7	21.4	4.0	108	23.0	3163	3881	44.9
T_3	Si-CU @ 90 kg N ha^{-1}	68.7	12549	204.0	22.1	4.2	126	24.4	4092	4930	45.4
T_4	Si-CU @ 120 kg N ha^{-1}	101.8	18223	289.0	25.1	4.4	174	27.6	6249	7114	46.7
T_5	Si-CU @ 150 kg N ha^{-1}	81.1	14678	238.7	23.2	4.2	146	25.8	5014	5867	46.1
T_6	CWOCU @ 60 kg N ha^{-1}	53.2	9822	159.0	21.9	3.8	101	22.8	3094	3752	45.2
T_7	CWOCU @ 90 kg N ha^{-1}	66.7	12304	195.3	22.4	3.9	123	24.1	3975	4571	46.6
T_8	CWOCU @ 120 kg N ha^{-1}	97.8	17691	284.0	24.9	4.3	169	26.8	6025	6957	46.3
T_9	CWOCU @ 150 kg N ha^{-1}	80.6	14618	227.7	23.5	4.1	145	25.7	5002	5625	47.1
T_{10}	Control (No nitrogen)	42.0	7877	137.6	21.2	3.5	86	21.1	2320	2842	44.9
	SEm(±)	3.34	566	6.7	0.94	0.19	4.6	1.29	211	192	1.6
	CD(0.05)	9.94	1683	20.0	NS	NS	14	NS	628	572	NS

Table 2. Effect of different levels and source of slow urea fertilizer on post harvest nutrient status of soil

Treatment		Post harvest soil nutrients status (kg/ha)		
		Available N	**Available P**	**Available K**
T_1	NCU @120 kg N ha^{-1}	331.3	34.8	327.7
T_2	Si-CU@ 60 kg N ha^{-1}	221.0	27.5	278.3
T_3	Si-CU @ 90 kg N ha^{-1}	246.3	29.3	285.7
T_4	Si-CU @ 120 kg N ha^{-1}	333.7	35.0	330.3
T_5	Si-CU @ 150 kg N ha^{-1}	351.7	37.2	337.0
T_6	CWOCU @ 60 kg N ha^{-1}	227.0	27.3	288.7
T_7	CWOCU @ 90 kg N ha^{-1}	256.3	28.0	294.0
T_8	CWOCU @ 120 kg N ha^{-1}	336.0	33.9	318.0
T_9	CWOCU @ 150 kg N ha^{-1}	348.3	36.0	323.7
T_{10}	Control (No nitrogen)	196.0	25.1	263.0
	SEm (±)	11.0	1.2	12.4
	CD (0.05)	32.57	NS	NS

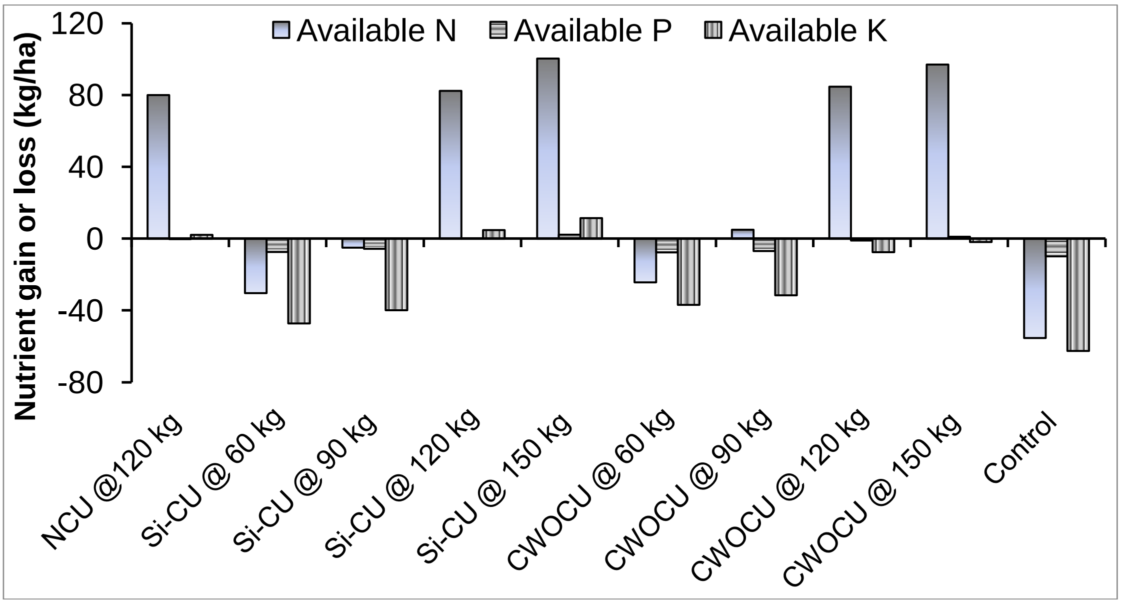

Fig. 1. Available soil nutrient gain or loss over initial status after harvest of the rice crop

Table 3. Effect of different levels and source of slow releasing coated urea on economics of wet direct seeded rice

Treatment		Cost of cultivation (₹. ha^{-1})	Gross Returns (₹. ha^{-1})	Net Returns (₹. ha^{-1})	B-C Ratio
T_1	NCU @120 kg N ha^{-1}	38574	135896	97322	2.52
T_2	Si-CU@ 60 kg N ha^{-1}	38146	72914	34767	0.91
T_3	Si-CU @ 90 kg N ha^{-1}	38658	94154	55496	1.44
T_4	Si-CU @ 120 kg N ha^{-1}	39170	142964	103793	2.65
T_5	Si-CU @ 150 kg N ha^{-1}	39683	115030	75347	1.90
T_6	CWOCU @ 60 kg N ha^{-1}	38098	71248	33149	0.87
T_7	CWOCU @ 90 kg N ha^{-1}	38587	91026	52440	1.36
T_8	CWOCU @ 120 kg N ha^{-1}	39075	138030	98955	2.53
T_9	CWOCU @ 150 kg N ha^{-1}	39563	114297	74735	1.89
T_{10}	Control (No nitrogen)	37122	53469	16347	0.44
	SEm (±)		4301	4301	0.111
	CD (0.05)		12780	12780	0.33

of available nitrogen (-30.3 and -24.3 kg N ha^{-1}) as compared to other treatments. Si-CU and CWOCU @ 150 kg N ha^{-1} applied plots recorded the highest gain of soil available phosphorus (2.27 and 1.12 kg P_2O_5 ha^{-1}) over initial status. The plots received Si-CU @ 150 kg N ha^{-1} showed little gain of soil available potassium (11.5 kg K_2O ha^{-1}) over initial status. Plots applied with silicon coated slow release urea @ 120 kg N ha^{-1} showed very little gain of soil available potassium (2.17 kg K_2O ha^{-1}).

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 fertilizers (Table 3). Among the different treatments, highest gross returns were recorded with application of 100 per cent RDN through Si-CU (₹.142964 ha^{-1}) which was on par with 100 per cent RDN applied through CWOCU (₹.138030 ha^{-1}) and NCU (₹.135896 ha^{-1}). Similar trend of maximum net returns were also obtained in the plots applied with 100 per cent RDN through Si-CU and CWOCU (₹. 103793 ha^{-1} and ₹. 98955 ha^{-1}, respectively) which was on par with 100 per cent RDN through NCU (₹. 97322 ha^{-1}) [21]. The higher gross and net returns were mainly attributed to higher grain and straw yields. Similar findings were also observed by Kumar et al. [12] and Chakraborty et al. [22].

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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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