

Optimizing rice (*Oryza sativa*) growth, productivity, profitability and nutrient uptake with coated urea and organic manure in the new alluvial zone of West Bengal

SUSMITA DAS¹, SUKANTA PAL², HIRAK BANERJEE³, AMIT KUMAR⁴ AND TANMOY SHANKAR⁵

Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, Nadia 741 252, West Bengal

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ABSTRACT

A two-year field experiment was carried out at experimental farm of BCKV, Nadia, West Bengal during *kharif* seasons of 2019–20 and 2020–21 to study the effect of combined application of coated urea and organic manure on performance of rice. The experiment was laid-out in a randomized complete block design with four replications and treatment comprised 5 treatment combinations, such as T₁, control plot (without N); T₂, 100% recommended dose of nitrogen (RDN) through neem-coated urea (NCU); T₃, 75% RDN through NCU + 25% RDN through FYM (farm yard manure); T₄, 100% RDN through polymer sulphur coated urea (PSCU); T₅, 75% RDN through PSCU+25% RDN through FYM. The results showed that 75% RDN through PSCU+25% RDN through FYM resulted in maximum growth attributes, viz. plant height (110.8 cm), maximum number of effective tillers per square meter (416/m²), highest dry-matter accumulation (DMA) (740 g/m²), leaf area index (LAI) (4.47) and crop growth rate (CGR) (6.56 g/m²/day), highest yield components like panicle length (23.5 cm), panicle weight (9.95 g), number of filled grains/panicle (113), test-weight (21.3 g) and maximum grain yield (4.79 t/ha) and straw yield (5.53 t/ha). Similarly, maximum amount of total nutrient uptake by crop (99.7, 40.1 and 208 kg/ha NPK), protein yield (418 kg/ha), gross returns (₹ 71.8 × 10³ /ha), net return (₹ 52 × 10³ /ha) and B: C ratio (2.73) were noticed under T₅ treatment. Therefore, it is advisable to implement a comprehensive nutrient management strategy T₅ (75% RDN through PSCU + 25% RDN through FYM) in rice cultivation. This approach enhances growth, yield, nutrient absorption, and quality, ultimately boosting agricultural productivity, profitability, and sustainability.

Key words: Nutrient acquisition, Organic sources of nutrients, Productivity, Profitability, SCU

Rice (*Oryza sativa* L.) holds significant importance as a cereal crop, both in India and globally. It serves as a staple food grain for over 50% of the global population. India, specifically, boasts the largest rice cultivation area spanning 46.38 million ha, making it the second-largest producer worldwide with a production volume of 130.29 million tonnes (mt). The average productivity in India stands at 2.81 t/ha (GoI, 2022). In the state of West Bengal, rice cultivation covers approximately 5.8 million ha, resulting in a production of 16.6 million tonnes and with a 2.60 t/ha productivity, which is far below the national average. Vari-

ous reasons for low productivity are cultivation of long-duration local cultivars, non-availability of seeds of high-yielding varieties, low solar radiation, high incidence of insect-pests, diseases and weeds, and poor N management (Gounda *et al.*, 2023). Rice is a well-established cereal crop, having high nutrient requirements, particularly for N. Effective N management is a crucial aspect of modern farming practices. The growing global population is driving an increased demand for rice, posing challenges for sustainable rice cultivation practices. One crucial aspect of rice cultivation is optimization of fertilization practices to ensure not only high yields but also environmental sustainability (Shahzad *et al.*, 2019). Traditional fertilizers, such as ordinary urea, have been widely used in rice cultivation. However, the efficiency of N use in cereals, especially heavy feeder crops like rice, is often compromised due to various losses associated with ordinary urea. These losses include NO₃⁻² leaching, NH₃ volatilization, and denitrification, which collectively result in reduced N use efficiency (Sun *et al.*, 2020). One promising approach to mitigate these losses and enhance N-use efficiency is the

Corresponding author's Email: susmitadas282@gmail.com

¹Assistant Professor, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, Nadia 741 252, West Bengal, ²Professor, ³Associate Professor, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, Nadia 741 252, West Bengal; ⁴Scientist, ICAR Research Complex for NEH Region, Sikkim Centre, Tadong, Gangtok 737 102, Sikkim; ⁵Associate Professor, Department of Agronomy and Agroforestry, M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi 761 211, Odisha

use of coated urea. Coated urea involves encapsulating the nitrogen-containing granules with a protective layer (sulfur or polymers), acts as a barrier, allowing for slow or controlled release of nutrient into the soil (Rehman *et al.*, 2022). This controlled release not only minimizes N losses (leaching, volatilization, and denitrification) but also ensures a sustained and steady supply of N to the plants, optimizing nutrient uptake (Kumar *et al.*, 2024). The slow-release characteristics of coated-urea ensure a sustained supply of nitrogen to plants over an extended period, aligning nutrient availability more closely with the crop's demand. This not only reduces the need for frequent applications but also minimizes the risk of environmental pollution. Additionally, the controlled release allows for better synchronization between nutrient availability and the various growth stages of the rice plant (Samant *et al.*, 2023).

The importance of organic manure in sustainable agriculture has also been widely recognized. Organic manure serves as a rich source of essential nutrients, providing a balanced and diverse array of elements necessary for the healthy growth of rice plants. Unlike synthetic fertilizers that often supply a limited set of nutrients, organic manure contains macronutrients, such as nitrogen, phosphorus, and potassium, as well as micronutrients like zinc, copper, and manganese (Karki *et al.*, 2023). This comprehensive nutrient profile ensures that rice plants receive a holistic and well-rounded diet, reducing the risk of nutrient deficiencies and promoting overall vigor. Organic manure, derived from plant or animal sources, contributes to soil health, enhances microbial activity, and provides a diverse range of nutrients essential for plant growth. Organic manure acts as a microbial stimulant, fostering the growth and activity of beneficial microorganisms in the soil (Pathak *et al.*, 2023). Organic manure stands as a cornerstone for sustainable rice cultivation. Its multifaceted benefits, ranging from nutrient enrichment and soil structure improvement to environmental sustainability, make it an invaluable input in modern agricultural systems. When used in conjunction with synthetic fertilizers like coated urea, organic manure has the potential to synergistically enhance the overall nutrient availability to plants (Rehman *et al.*, 2022). Thus, the combined application of coated-urea and organic manure presents an intriguing avenue for improving the growth, productivity, profitability, and nutrient acquisition of rice. While individual studies have explored the effects of coated urea or organic manure on rice cultivation, there is a noticeable gap in the research regarding their conjoint application. Understanding the interactive dynamics and potential synergies between these two fertilizers is crucial for developing holistic and sustainable fertilization strategies for rice crops. In this context, a field experiment was conducted for two consecutive years to investigate the im-

pact of conjoint application of coated urea and organic manure on growth, productivity, profitability and nutrient acquisition of rice.

MATERIALS AND METHODS

An experiment for two years duration (2019–20 and 2020–21) was conducted at the D-Block farm of BCKV, Nadia, West Bengal. The experimental site is situated at a latitude of 22°98'N and longitude of 84°42'E, with an altitude of 9.50 m above mean sea level (MSL). This region has hot, sub-humid to humid climate. The temperature reached a maximum of 34°C in the month of May and minimum temperature got down to 23°C in the month of October during the crop growing season. The site receives an average annual rainfall of 1440 mm. The soil sample were collected before sowing of *kharif* rice and analyzed therefore. Soil of experimental site was clay loam in texture having bulk density 1.45 Mg/m³ with a neutral soil reaction, low levels of organic carbon (0.49 percent) and available N (205.3 kg/ha), high level of available P (28.8 kg/ha), and medium level of available K (175.5 kg/ha). The experiment was laid-out in a randomized complete block design (RCBD) with four replications and treatments comprised of five treatment combination such as T₁, Control plot (without N); T₂, 100% RDN through neem coated urea (NCU); T₃, 75% RDN through NCU + 25% RDN through FYM (farm yard manure); T₄, 100% RDN through polymer sulphur coated urea (PSCU); T₅, 75% RDN through PSCU + 25% RDN through FYM. The 21 days old rice seedlings of 'Satabdi' variety were transplanted on June 20th, 2019 and June 7th, 2020 respectively, with crop geometry of 20 cm (row to row), and 10 cm (plant to plant spacing). The recommended dose of fertilizers for rice was 150 kg N/ha, 80 kg P/ha, and 60 kg K/ha. The nutrients were supplied through NCU (46% N), PSCU (36% N), SSP (16% P₂O₅) and MOP (60% K₂O) and FYM (0.50% N, 0.25% P₂O₅ and 0.50% K₂O). The prescribed treatments for rice cultivation involved the application of the full amount of farmyard manure (FYM), phosphorus (P), and potassium (K), along with half the dose of nitrogen (N) prior to the transplanting of rice seedlings. The remaining 50% N was administered in line with the recommended treatment schedule in 2-splits during the vegetative stage, and the remaining N split equally—25% at the early tillering stage and 25% at the panicle initiation stage. The harvesting of rice was conducted on October 9, 2019 and October 18, 2020 respectively. The recommended cultivation practices were followed throughout the crop duration. The observations for growth and yield attributes were taken from the standing rice crop. From the 5 tagged plants of rice, plant height was recorded from the ground to the tip of the panicle by meter scale (cm). Leaves of these plants were also used for

calculation of leaf area with the help of leaf area meter (Model LI-COR-3100) and the leaf area index/plant was calculated by using the following formula:

$$LAI = \frac{\text{Total leaf area/plant (cm}^2\text{)}}{\text{Ground area occupied/plant (cm}^2\text{)}}$$

The culms, leaves, and panicles of the above mentioned collected samples were separated, air-dried in the shade, followed by drying in the hot-air oven at 70 °C till a constant weight was obtained in gram. This dry weight was used for the calculation of mean crop growth rate. The mean crop growth rate was worked out with the following formula, it expressed as g/m²ground area/day.

$$CGR = \left(\frac{W_2 - W_1}{T_2 - T_1} \right) \left(\frac{1}{S} \right)$$

Where,

W_1 and W_2 are dry weight (g) of plants at time T_1 and T_2 , respectively

$T_2 - T_1$ is the interval of time in days

S is land area (m²) occupied by plants

When the rice reached harvest stage, the tillers in one-meter-square area were counted and expressed as tiller number/m². Five panicles were chosen at random, and the grains from each panicle were counted, averaged, and represented as the total number of grains per panicle. Number of filled grains/panicle from randomly selected panicles were counted. Mean of five panicles was arrived and expressed as number of filled grains/panicle. Thousand grains were drawn randomly from the composite sample of grain yield obtained from each of the net plot area, weighed and expressed as test weight in gram. Manual labour was used to harvest each plot's net area. The product was exposed to sunlight. Plot-wise threshing of the bundles was then done. The grains underwent separate winnowing, followed by 4 days of cleaning and sun-drying. Separate weights were recorded for grain, straw, and chaff. Grain and straw yields have been reported @ 14% moisture content. Samples of grain and straw were prepared for nutritional analysis. Samples were first dried in an oven at 65°C until a constant weight was reached. After that, they were ground in a Willey mill fitted with stainless steel blades. The amount of N (%) in grain and straw was estimated using a modified Kjeldahl technique. Using a UV-VIS spectrophotometer set at 420 nm, the vanadomolybdophosphoric acid yellow colour technique was used to measure the P content of grain and straw. The K concentration in grain and straw was determined by flame photometer. Nutrient uptake was calculated by using the following expression:

N uptake (kg/ha) in grain/straw = [% nutrient in grain/straw × grain/straw yield (kg/ha)]

The N content (%) was multiplied by a conversion factor of 6.25 to estimate the protein content in the grains.

This conversion is derived from the nitrogen content, which typically constitutes 16% of rice protein. Calculating protein yield was done using the following formula:

Protein yield (kg/ha) = Protein content (%) × grain yield (kg/ha)/100

The total value of the output was quantified in monetary terms, and determined using the following formulas:

Gross returns (₹/ha) = Value of the grain (₹/ha) + Value of the straw (₹/ha)

Net returns (₹/ha) = Gross returns (₹/ha) – Total costs (₹/ha)

B: C ratio = Net returns (₹/ha) / Total cost (₹/ha)

The data generated from the characters under study for both the year was analyzed using Fisher's method of ANOVA as described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth parameters

The results showed that maximum plant height (110.8 cm), DMA (740 g/m²) and LAI (4.47) were recorded in T_5 treatment which was statistically at par with T_3 treatment and significantly better than remaining treatments. The highest value of CGR (6.56 g/m²/day) was noticed under T_5 treatment which was significantly higher than T_1 and stood at par with other treatments. It might be due to slow release of N from coated urea over time owing to its protective coating, providing a sustained supply of nitrogen to the plants. This helps in maintaining a consistent nutrient availability throughout the plant growth cycle, which is essential for optimal growth and development (Rehman *et al.*, 2022).

Yield attributes and yield

A maximum number of tillers/m² (416), panicle length (23.5 cm), panicle weight (9.95g) and 1,000-grain weight (21.3 g) were noticed under T_5 followed by T_3 treatment. The maximum number of filled grains/panicle was observed under T_5 which were statistically at par with T_2 , T_3 , T_4 treatments and significantly higher than T_1 . Similarly, T_5 resulted in significant improvement in grain yield by 103%, straw yield by 90% as compared to other treatments respectively. It might be due to wide range of essential nutrients in organic manure besides nitrogen, such as phosphorus, potassium, and micronutrients. The addition of organic manure alongside coated urea helps in supplying a balanced range of nutrients to the plants, ensuring that their nutritional requirements are adequately met throughout the growing season (Sun *et al.*, 2020). The release pattern of N from the PSCU enhanced the test weight due to larger carbohydrate assimilation and steady nutrient translocation to the panicle from other organs (Sun *et al.*, 2020).

Table 1. Effect of coated urea and organic manure on the growth attributes of rice at different growth stages (pool data of 2019–20 and 2020–21)

Treatment	Plant height at harvest stage (cm)	DMA at harvest stage (g/m ²)	Leaf area index at maximum growth stage	Crop growth rate at maximum stage (g/m ² /day)	Number of tillers/m ²	Panicle length (cm)	Panicle weight (g)	Number of grains/panicle	1000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Gross returns (× 10 ³) (₹/ha)	Net returns (× 10 ³) (₹/ha)	Benefit: cost ratio
T ₁	97.7	523.9	3.70	3.72	270.3	18.6	6.63	94.0	18.5	2.35	2.91	35.2	19.3	2.22
T ₂	104.6	613.3	3.96	5.31	354.9	20.2	8.12	107.0	19.4	3.92	4.91	58.7	41.5	3.41
T ₃	109.7	733.2	4.38	6.20	377.9	22.7	9.49	112.9	20.5	4.47	5.39	66.9	48.8	3.70
T ₄	104.8	661.8	4.08	5.69	325.3	21.3	8.66	110.0	20.2	4.35	5.32	65.2	46.4	3.47
T ₅	110.8	740.0	4.47	6.56	415.9	23.5	9.95	113.0	21.3	4.79	5.53	71.8	52.5	3.73
SEM±	1.81	15.61	0.05	0.61	15.61	0.60	0.24	2.20	0.34	0.01	0.02	1.27	1.23	0.01
CD (P=0.05)	5.21	45.08	0.15	1.76	45.08	1.60	0.69	6.40	0.98	0.03	0.07	4.97	4.79	0.04

T₁, [N0 + 100% PK]; T₂, 100% N (NCU) + PK; T₃, [75% NPK (N as NCU) + 25% N by FYM during kharif; T₄, 100% N (PSCU) + PK; T₅, [75% NPK (PSCU) + 25% N by FYM during kharif; DAT, Days after transplanting; NS, Non-Significant at P > 0.05

Nutrient content (%) and uptake (kg/ha)

Different nutrient management practices showed significant effect on nutrient content and uptake by crop (Table 2). Among the different nutrient management practices, treatment T₅ recorded the highest amount of nutrient content in grain (1.40% N, 0.48% P, 2.38% K) and Straw (0.59% N, 0.31% P, 1.70% K) compared to other treatments. This might be due to coated urea and organic manure release nutrients gradually over time. This sustained release pattern ensures a steady supply of nutrients to the plants, minimizing nutrient stress and optimizing nutrient uptake efficiency. As a result, plants can maintain higher nutrient levels in their tissues, promoting healthier growth and development (Shahzad *et al.*, 2019). Similarly, maximum amount of total nutrient uptake by crop (99.7, 40.1 and 208 kg/ha NPK) was found under T₅ treatment. This might be due to enhanced soil fertility and improved nutrient availability by providing organic matter that serves as a reservoir for nutrients. The decomposition of organic matter releases nutrients gradually, making them more readily available to plant roots over an extended period. Coated urea, with its slow-release properties, further extends the availability of nitrogen. This increased availability of nutrients in the root zone stimulates greater nutrient uptake by plants, leading to higher total nutrient uptake (Samant *et al.*, 2023).

Protein content (%) and protein yield (kg/ha)

Among the quality parameters, protein content was not influenced by different nutrient management practices but protein yield was significantly influenced across the study year. The maximum protein yield (418 kg/ha) was recorded under T₅ which was statistically at par with T₃ and significantly higher than other treatments. It might be due to the fact that coated urea provides a slow and sustained release of nitrogen, while organic manure contributes various nutrients including nitrogen, phosphorus, and potassium. A balanced supply of nutrients is essential for the synthesis of proteins in plants. The combination of these fertilizers ensures that plants have access to sufficient nitrogen as well as other essential nutrients needed for protein synthesis, resulting in higher protein content in crops (Rehman *et al.*, 2022). Shahzad *et al.* (2019) stated that coated urea reduces nitrogen losses through leaching and volatilization, making more nitrogen available for plant uptake. Organic manure enhances soil fertility and microbial activity, promoting the efficient uptake and utilization of nitrogen by plants. As a result, the nitrogen supplied by both fertilizers is utilized more effectively for protein synthesis, leading to increased protein content in crops (Karki *et al.*, 2023; Manjappa, 2023).

Table 2. Effect of coated-urea and organic manure on the nutrient uptake and economics of rice at different growth stages (pooled data of 2019–20 and 2020–21)

Treatment	Nutrient content in grain (%)			Nutrient content in straw (%)			Nutrient uptake by grain (kg/ha)			Nutrient uptake by straw (kg/ha)			Total nutrient uptake by crop (kg/ha)			Protein content (%)	Protein yield (kg/ha)
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K		
	T ₁	1.15	0.33	2.23	0.42	0.15	1.55	27.0	7.76	52.4	12.2	4.37	45.1	39.2	12.1		
T ₂	1.26	0.39	2.28	0.49	0.21	1.61	49.4	15.3	89.4	24.1	10.3	79.1	73.5	25.6	169	7.84	307
T ₃	1.37	0.45	2.35	0.55	0.27	1.68	61.2	20.1	105.0	29.6	14.6	90.6	90.8	34.7	196	8.56	383
T ₄	1.32	0.44	2.33	0.50	0.24	1.64	57.4	19.1	101.4	26.6	12.8	87.2	84.0	31.9	189	8.25	359
T ₅	1.40	0.48	2.38	0.59	0.31	1.70	67.1	23.0	114.0	32.6	17.1	94.0	99.7	40.1	208	8.72	418
SEM±	0.01	0.00	0.01	0.00	0.00	0.002	0.19	0.10	0.16	0.14	0.10	0.23	2.22	1.10	3.98	0.03	13
CD (P=0.05)	0.02	0.01	0.02	0.01	0.01	0.005	0.43	0.22	0.36	0.33	0.24	0.53	6.75	3.24	12.5	NS	40

T₁, [N0 + 100% PK]; T₂, 100% N (NCU) + PK; T₃, [75% NPK (N as NCU) + 25% N by FYM during kharif; T₄, 100% N (PSCU) + PK; T₅, [75% NPK (PSCU) + 25% N by FYM during kharif; DAT, Days after transplanting; NS, Non-Significant at P > 0.05

Economics

Highest amount of gross returns (₹ 71.8 × 10³/ha), net return (₹ 52 × 10³/ha) and B: C ratio (2.73) were noticed under T₅ as compared to the other treatments but T3 treatment recorded the similar results. The combined application of coated urea and organic manure improves soil fertility, structure, and microbial activity. Healthy soils produce healthier crops with improved resistance to pests and diseases, resulting in higher yields and better crop quality. Higher productivity translates to increased revenues for farmers, offsetting the initial investment in fertilizers (Pathak *et al.*, 2023; Kumar *et al.*, 2024). Coated-urea minimizes nitrogen losses through leaching and volatilization, ensuring that a greater proportion of applied nitrogen is utilized by plants. Organic manure contributes to soil organic matter, enhancing nutrient retention and availability. Together, these fertilizers increase nutrient-use efficiency, allowing farmers to achieve optimal crop yields with lower fertilizer inputs, thus reducing production costs per unit of output (Kaur *et al.*, 2023).

Overall, the study underscores the efficacy of treatment T₅, employing 75% RDN through PSCU combined with 25% RDN through FYM, in maximizing growth attributes, yield components, nutrient uptake, and quality parameters in rice cultivation. T₅ exhibited superior performance across various parameters, including plant height, tiller count, DMA, LAI, CGR, panicle characteristics, grain and straw yields, total nutrient uptake, protein yield, as well as economic indicators such as gross returns, net returns, and Benefit to cost (B: C) ratio. Therefore, adopting a holistic nutrient management approach like T₅ can significantly enhance agricultural productivity, profitability, and sustainability in rice cultivation.

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