D-5824
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RESEARCH ARTICLE Agricultural Science Digest

Impact of Precision Nutrient Management on Rice Growth and Productivity in Southern Odisha

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10.18805/ag.D-5824

ABSTRACT

Background: Despite the emergence of numerous smart tools in recent times, a significant research gap still exists in identifying the most effective smart tool that optimally synchronizes fertilizer application with crop requirements, thereby promoting crop growth and productivity in accordance with the principles of SSNM.

Methods: The present investigation took place at the PG Experimental Farm, MSSSoA, CUTM, Odisha, during the *boro* season of 2021-22.The experiment followed a randomized block design, with eleven treatments that were replicated three times. The investigated treatments included the following: T_1- absolute control (no fertilizer), T_2- 75% of the recommended dose of fertilizer (RDF), T_3- 100% RDF, T_4- 125% RDF, T_5- 75% RDF followed by a spray of nano urea at a rate of 2ml/L during panicle initiation, T_6- 100% RDF followed by a spray of nano urea at a rate of 2 ml/L during panicle initiation, T_7 - leaf colour chart (LCC) 3 based nitrogen management, T_8- LCC 4 based nitrogen management, T_9- Sufficiency Index (SI)-based nitrogen management at SI<90%, T_{10}- Nutrient expert (NE)-based nutrient recommendation and T_{11}- Rice crop manager (RCM)-based nutrient recommendation.

Result: The study found that implementing nitrogen management based on site-specific information, using a total of 150 kg of nitrogen per hectare applied in four separate applications (at the basal stage, 28 days after transplanting, 42 days after transplanting and 63 days after transplanting), along with consistent levels of phosphorus and potassium, led to a 16.68% increase in grain yield and a 13.17% increase in biological yield for rice. This approach outperformed the traditional method of applying 100% recommended dose of fertilizer with 120 kg of nitrogen at fixed time intervals (basal, active tillering and panicle initiation).

Key words: Leaf colour chart, Nano urea, Nutrient expert, Rice crop manager, Sufficiency index.

INTRODUCTION

Rice serves as a primary food crop for more than half of the world's population and the introduction of high-yielding and fertilizer-responsive varieties during the Green Revolution played a crucial role in ensuring global food security (Fahad *et al*., 2019). With the projected population growth of 9 billion by 2050, there is a pressing need to increase rice production while dealing with limited land resources (Timsina *et al*., 2023). Effective fertilizer management is a vital factor in improving soil fertility and narrowing the yield gap.

During the early years of the Green Revolution, there was a notable rise in agricultural yields as a result of the increased use of fertilizers (Eliazer Nelson *et al*., 2019). However, in subsequent years, the growth in yields experienced to slow down comparatively. Proper nutrient supply is essential for optimal soil and crop management and increasing fertilizer inputs significantly enhance rice productivity (Rollon *et al*., 2021). However, farmers often apply excessive nitrogen and insufficient amounts of phosphate and potassium fertilizers, leading to increased pest prevalence, diseases and lodging (Aziz *et al*., 2018).

Standardized fertilizer recommendations do not adequately provide the optimal quantity of nutrients required for agricultural systems, leading to either excessive or insufficient nutrient application. This limitation hampers the efficient utilization of nutrients in crop production (Sanyal *et al*., 2014). Excessive fertilizer application can also lead to nutrient leakage and environmental contamination, including surface and groundwater pollution (Craswell, 2021). To address these challenges and maintain long-term environmental and agricultural sustainability, the adoption of precision nutrient management in rice cultivation has become crucial (Parihar *et al*., 2020 and Sharma *et al*., 2019). This approach involves synchronizing fertilizer application with crop needs. Numerous smart tools and decision support systems are available to determine the precise timing and appropriate dosage of primary nutrients tailored to specific sites. These tools rely on continuous monitoring and surveying to optimize nutrient management strategies. To date, there has been limited research on assessing the most effective smart or decision support tool

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How to cite this article: Sagar, L., Maitra, S., Singh, S. and Sairam, M. (2023). Impact of Precision Nutrient Management on Rice Growth and Productivity in Southern Odisha. Agricultural Science Digest. DOI:10.18805/ag.D-5824.

Submitted: 19-06-2023 **Accepted:** 27-07-2023 **Online:** 09-08-2023

for synchronizing fertilizer application with crop needs while ensuring optimal food production. Therefore, the current study aims to address this research gap.

MATERIALS AND METHODS

The research was conducted during the boro season of 2021-22 at the PG Experimental Farm of M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management in Odisha, India. The experimental farm is situated at coordinates 18°48′18″N and 84°10′45″E, with an elevation of 88 meters above sea level. The study was carried out under irrigated conditions.

The soil in the experimental field was sandy loam in texture and slightly acidic, with a pH value of 6.23. The soil had low levels of organic carbon (0.34%) and available nitrogen (176 kg/ha), while phosphorus (16 kg/ha) and potassium (127 kg/ha) levels were considered medium. The rice variety Naveen (IET 14461, CR 749-20-2) was sown on December 8, 2021, using a seed rate of 40 kg/ha in the nursery. The seedlings were later transplanted to the main field on January 7, 2022. The application of fertilizers was carried out according to the prescribed treatments (Table 1).

The experiment followed a randomized block design, with eleven treatments that were replicated three times. The investigated treatments included the following: T_1-absolute control (no fertilizer), T_2-75% of the recommended dose of fertilizer (RDF), T_3-100% RDF, T_4-125% RDF, T_5-75% RDF followed by a spray of nano urea at a rate of 2 ml/L during panicle initiation, T_6-100% RDF followed by a spray of nano urea at a rate of 2 ml/L during panicle initiation, T_7-leaf colour chart (LCC) 3 based nitrogen management,, T_8-LCC 4 based nitrogen management, T_9-Sufficiency Index (SI)-based nitrogen management at SI<90%, T_{10}- Nutrient expert (NE) based nutrient recommendation and T_{11}- Rice crop manager (RCM) based nutrient recommendation.

The collected experimental data for different parameters were subjected to statistical analysis using analysis of variance (ANOVA). The standard error of means (SEm±) and the critical difference at a significance level of p = 0.05 were calculated for the analysis. The methodology employed for statistical analysis was based on the approach outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth parameters

Precision nutrient management had a significant impact on the plant height and dry matter accumulation per square meter in rice at harvest, as indicated in Table 2. The SI-based N management treatment resulted in the highest plant height and dry matter accumulation. In terms of plant height and dry matter accumulation, these treatments exhibited a substantial increase of 26.01% and 80.58%, respectively, compared to the absolute control, which had the lowest values among all the treatments being compared. Regarding plant height, treatments such as the 125% RDF, LCC 4 based nitrogen management, 100% RDF followed by nano urea spray at 2 ml/L during panicle initiation, 100% RDF, RCM-based nutrient recommendation and NE-based nutrient recommendation showed comparable results to the superior treatment. Similarly, for dry matter accumulation, the 125% RDF treatment showed comparable performance to the superior treatment. The provision of nutrients in a timely manner and in sufficient amounts supports the synthesis of protoplasm and promotes vigorous growth of the plant. When nitrogen levels are increased, especially with adequate supplies of phosphorus and potassium, the plant is able to absorb nutrients more effectively, leading to rapid expansion of foliage and ultimately promoting overall growth. The results obtained were similar to the earlier findings (Subedi *et al*., 2019; Ali *et al*., 2015 and Bhat *et al*., 2022).

Yield and yield attributes

Precision nutrient management had a significant impact on all yield components of rice, except for test weight. Results from Table 3 showed that the number of effective tillers per square meter, number of spikelets per panicle and number of filled spikelets per panicle were notably affected by different precision nutrient management treatments. In particular, the SI-based N management treatment demonstrated superior performance, exhibiting a 34.09%

Table 1: Treatment wise fertilizer application schedule.

Treatments	Number of splits	Time of N split application	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Nano urea
T_1	Nil	NIL	0	0	0	-
T_2	3	Basal, AT, PI	90	45	45	-
T_3	3	Basal, AT, PI	120	60	60	-
T_4	3	Basal, AT, PI	150	75	75	-
T_5	3	Basal, AT, PI	90	45	45	2 ml/L
T_6	3	Basal, AT, PI	120	60	60	2 ml/L
T_7	3	Basal, 35 DAT, 49 DAT	99	60	60	-
T_8	4	Basal, 21 DAT, 35 DAT, 49 DAT	132	60	60	-
T_9	4	Basal, 28 DAT, 42 DAT, 63 DAT	150	60	60	-
T_{10}	3	Basal, 15 DAT, 30 DAT	109	35	58	-
T_{11}	3	Basal, 26 DAT, 43 DAT	112	32	25	-

*AT= Active tillering; PI= Panicle initiation; DAT= Days after transplanting.

increase in the number of effective tillers per square meter, a 40.22% increase in the number of spikelets per panicle and a remarkable 52.70% increase in the number of filled spikelets per panicle compared to the absolute control. It is worth noting that the test weight, being a stable varietal characteristic, did not exhibit significant variations due to precision nutrient management. The appropriate timing of nitrogen application through consistent monitoring could have contributed to a prolonged period of leaf greenness. This, in turn, resulted in increased levels of active photosynthesis during the ripening stage. The extended photosynthetic activity was the primary factor behind the larger capacity of the grain storage area and a reduced number of unfilled spikelets. These findings are in conformity with Moharana *et al*. (2017); Pradhan *et al*. (2021) and Hemalata *et al*. (2020).

The application of precision nutrient management had a significant impact on various yield parameters of rice as indicated in Table 4. The results clearly demonstrated that nitrogen management based on the sufficiency index (SI) led to significantly higher grain and biological yield than absolute control and it was closely followed by the application of 125% recommended dose of fertilizer (RDF). However, when it came to straw yield, 125% RDF outperformed the other treatments, but was comparable to SI-based nitrogen management. The implementation of SI-based nitrogen management resulted in a 16.68% increase in grain yield and a 13.17% increase in biological yield of rice, compared to the application of 100% RDF at fixed time intervals. The possible reason for the increased grain yield could be attributed to the improved growth and yield attributing characters, leading to larger grain storage capacity and effective transportation of nutrients from the source to the grain. This could have resulted in a higher number of grains being filled, thereby increasing the overall grain yield. Similar findings were reported by Santos *et al*. (2019; Singh and Khind (2015) and Hussain *et al*. (2000). On the other hand, the application of 125% RDF led to a 10.68% increase in straw yield compared to 100% RDF and a substantial 65.11% increase compared to the absolute control. However, the straw yield obtained from 125% RDF was comparable to that obtained from 100% RDF and harvest index was not

Table 2: Influence of precision nutrient management on growth parameters of rice at harvest.

Treatments	Plant height (cm)	Dry matter accumulation (g/m^2)
Absolute control	96.23	680
75% RDF	105.65	891
100% RDF	112.46	1069
125% RDF	118.28	1224
75% RDF *fb* nano urea spray @ 2 ml/L at panicle initiation	107.34	966
100% RDF *fb* nano urea spray @ 2 ml/L at panicle initiation	115.63	1127
LCC 3 based nitrogen management	108.82	978
LCC 4 based nitrogen management	117.68	1176
SI-based nitrogen management	121.26	1228
NE-based nutrient recommendation	109.29	987
RCM-based nutrient recommendation	111.75	1056
SEm (±)	4.12	38
CD (P=0.05)	12.24	112

Table 3: Influence of precision nutrient management on yield components of rice.

Treatments	Effective tillers per square meter	Number of spikelets per panicle	Number of filled spikelets per panicle	Test weight (g)
Absolute control	176	87	74	20.88
75% RDF	208	107	95	21.37
100% RDF	221	118	107	21.27
125% RDF	234	119	110	21.29
75% RDF *fb* nano urea spray @ 2 ml/L at panicle initiation	214	111	99	21.31
100% RDF *fb* nano urea spray @ 2 ml/L at panicle initiation	227	119	107	21.09
LCC 3 based nitrogen management	216	117	106	21.32
LCC 4 based nitrogen management	231	119	109	21.22
SI-based nitrogen management	236	122	113	21.16
NE-based nutrient recommendation	213	112	100	21.38
RCM-based nutrient recommendation	219	113	101	21.17
SEm (±)	11	5	4	1.03
CD (P=0.05)	31	14	13	NS

Table 4: Influence of precision nutrient management on yield parameters of rice.

Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest Index (%)
Absolute control	2715	3595	6310	43.05
75% RDF	3737	4508	8246	45.32
100% RDF	4572	5363	9935	46.06
125% RDF	5271	5936	11207	47.06
75% RDF *fb* nano urea spray @ 2ml/L at panicle initiation	4239	4731	8970	47.17
100% RDF *fb* nano urea spray @ 2ml/L at panicle initiation	4882	5537	10418	46.86
LCC 3 based nitrogen management	4359	4902	9261	47.15
LCC 4 based nitrogen management	5120	5851	10970	46.68
SI-based nitrogen management	5335	5909	11244	47.45
NE-based nutrient recommendation	4169	5164	9334	44.36
RCM-based nutrient recommendation	4431	5386	9817	45.27
SEm (±)	254	283	370	1.99
CD (P=0.05)	754	840	1100	NS

influenced significantly by different precision nutrient management practices under comparison.

CONCLUSION

The findings of this study strongly indicate that implementing SI-based nitrogen (N) management, along with recommended amounts of phosphorus and potassium, can be a successful approach for achieving increased grain yield in rice cultivation in Southern Odisha. SI-based N management closely matched the performance of applying 125% recommended dose of fertilizer (RDF), but with SI-based management, slightly lower quantities of phosphorus and potassium (approximately 15 kg less) were required. This suggests that SI-based N management at (SI<90%) can be an efficient alternative with comparable yield outcomes while optimizing the use of nitrogen. phosphorus and potassium fertilizers.

Conflict of interest: None.

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