D-5913
[1-6]

RESEARCH ARTICLE Agricultural Science Digest

Evaluation of Nutrient Levels, Optical Sensors and Decision Support Tools for Nitrogen Optimization in Rice during Dry Season

Lalichetti Sagar[1], Sagar Maitra[1], Sultan Singh[2], Masina Sairam[1], Angara Pavan[1]

10.18805/ag.D-5913

ABSTRACT

Background: Improving the efficiency of nitrogen utilization in rice is vital for achieving significant crop yields with minimum harm to the environment. To tackle this challenge, various portable optical sensors and decision-support tools have been emerging in recent times. However, there is currently a lack of comprehensive assessment and comparison of these tools with different levels of fertilizer recommendation with and without additional supplementation of nano urea.

Methods: The current study was carried out during the dry season of 2021 and 2022 at the P.G. Experimental Farm of Centurion University of Technology and Management. The investigated treatments encompassed the following: T_1: Absolute control, T_2: 90-45-45 (N-P_2O_5-K_2O kg/ha), T_3: 120-60-60 (RDF), T_4: 150-75-75, T_5: T_2+NU @ 2 ml/L at panicle initiation, T_6: T_3+NU @ 2 ml/L at panicle initiation, T_7: N application at LCC d™ 3, T_8: N application at LCC d™4, T_9: N application at SI < 90%, T_{10}: Nutrient Expert (TY: 5.5 t/ha), T_{11}: Rice crop manager (TY: 5.5t/ha) which were allocated in randomized block design with three replications.

Result: The findings showed that implementing nitrogen (N) application when the sufficiency index (SI) is below 90% led to a significant 16.85% boost to grain yield of rice compared to the application of 120-60-60 at fixed intervals as per the standard recommendation. In the former approach, 150 kg N/ha was applied in four splits. However, N application at a leaf color chart (LCC) value of 4 or less was considered efficient, with maximum agronomic efficiency (18.22 and 19.22 kg grain/kg N applied) and recovery efficiency (43.27% and 50.25%) observed in 2021 and 2022, respectively since, this approach resulted in a comparable yield increase and nitrogen absorption with a reduced nitrogen input.

Key words: Agronomic efficiency, Nitrogen uptake, Partial factor productivity, Precision nutrient management, Rice.

INTRODUCTION

A majority of the global population relies on rice as their primary dietary staple. In India, rice is cultivated on approximately 45.77 million hectares of land, yielding 124.37 million tonnes of rice with an average productivity of 2717 kg/ha (Anonymous, 2023a). In the state of Odisha, rice is grown on 4.04 million hectares, producing 8.81 million tonnes of rice at an average productivity of 2182 kg/ha (Anonymous, 2023b). Meeting the food requirements of a growing population with limited available farmland is a significant challenge to agriculture.

Efficient fertilizer management is a crucial strategy to bridge the gap between actual and potential rice crop yields (Chivenge *et al*., 2021). The Green Revolution demonstrated that increased nitrogenous fertilizer had a positive correlation with higher rice grain production. Nitrogen plays a crucial role in boosting rice crop growth and productivity (Keerthi *et al*., 2023). However, the application of nitrogen beyond the crop needs at inappropriate times results in soil degradation, water pollution and increased greenhouse gas emissions *etc*. (Singh *et al*., 2023). Hence, it is imperative to optimize the nitrogen supply and achieve maximum nitrogen use efficiency to sustain rice production.

Optimizing nitrogen in agriculture requires alignment of nitrogen fertilizer applications according to the specific needs of the crops through continuous monitoring (Swamy *et al*., 2022). This should be carried out in conjunction with the assurance of an adequate and well-balanced supply of phosphorus and potassium, as these elements are equally essential for enhancing the efficient utilization of nitrogen (Li *et al*., 2014). Taking this into consideration, different fertilizer grades, portable optical sensors and decision support tools based on nutrient management was compared to find out the most judicious combination of nitrogen, phosphorus and potassium that optimizes the nitrogen requirement in rice. Additionally, the fertilizer grades were supplemented by nano urea, a recent introduction by the Indian Farmers Fertilizer Cooperative Limited (IFFCO), to assess its unexplored

[1]Department of Agronomy, Centurion University of Technology and Management, Paralakhemundi-761 211, Odisha, India.
[2]Department of Agronomy, Sri Karan Narendra Agricultural University, Jobner-303 328, Jaipur, Rajasthan, India.

Corresponding Author: Lalichetti Sagar, Department of Agronomy, Centurion University of Technology and Management, Paralakhemundi-761 211, Odisha, India. Email: lalichetti.sagar@cutm.ac.in

How to cite this article: Sagar, L., Maitra, S., Singh, S., Sairam, M. and Pavan, A. (2023). Evaluation of Nutrient Levels, Optical Sensors and Decision Support Tools for Nitrogen Optimization in Rice during Dry Season. Agricultural Science Digest. DOI: 10.18805/ag.D-5913

Submitted: 07-11-2023 **Accepted:** 04-12-2023 **Online:** 18-12-2023

potential which may further help in saving nitrogen fertilizers without compromising the grain yield of rice.

MATERIALS AND METHODS

During the dry season of 2021 and 2022, a study was conducted at P.G. Research Farm, M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management. Odisha (18°48′N latitude, 84°10″E longitude with 88m height above mean sea level). The meteorological data was collected from an automatic weather station situated at Centurion University of Technology and Management, Parlakhemundi campus. The findings revealed that in 2021 (8th December, 2021 to 18th April, 2022), there was extremely limited rainfall, amounting to only 97.4 mm, while in 2022 (1st December, 2022 to 11th April, 2023), the region experienced a slightly higher total rainfall of 110 mm during the dry season. Throughout the period of investigation in both years, the maximum temperatures ranged from 27.4 to 40.7°C and the minimum temperatures varied between 12.3 and 26.7°C.

The research field had soil with a sandy loam texture and a slightly acidic pH level. The soil had low levels of organic carbon and available nitrogen but contained moderate amounts of phosphorus and potassium. The rice variety Naveen (IET 14461, CR 749-20-2), a medium duration variety with medium bold grains, evolved at the National Rice Research Institute (NRRI), Cuttack was selected for this experiment. There were a total of eleven treatments such as three graded levels of fertilizer without nano urea, two graded levels with nano urea, three nitrogen management approaches using optical sensors, two nutrient management approaches based on decision support tools and an absolute control which were allocated in randomized block design with three replications. Nitrogen, phosphorus and potassium were provided to the soil via different sources: urea for nitrogen, single super phosphate for phosphorus and muriate of potash for potassium. Additionally, IFFCO nano urea was utilized to supply nano urea. The specific fertilizer application schedule for both years is outlined in Table 1.

To evaluate the treatments and optimize the nitrogen dosage of rice cultivated during the dry season at the northeastern ghat zone of Odisha the mean yield *viz*., grain yield (kg/ha), straw yield (kg/ha), biological yield (kg/ha), harvest index (%) and nutrient uptake in grain and straw of rice were analyzed statistically using standard error of means (SEm±) and determined the least significant difference at a significance level of $p = 0.05$ according to the standard methodology (Gomez and Gomez, 1984). Further, the data analysis pack of Microsoft Excel software was used for statistical analysis.

RESULTS AND DISCUSSION

Influence of nutrient levels, optical sensors and decision support tools on yield and harvest index of rice

The study results (Table 2) indicated that the treatment T_9 (N application at SI < 90%) had noted significantly higher mean grain yield of rice (5379 kg/ha) and remained statistically at par with T_4 (150-75-75), T_8 (N application at LCC ≤4) and T_6 (T_3+NU @ 2 ml/L at panicle initiation). Moreover, the former treatment reported a 16.85% significant increase in the mean grain yield of rice in comparison with T_3 (120-60-60) which represented the recommended dose of fertilizer. The increased nitrogen application in treatments T_9, T_4 and T_8, as opposed to T_3, likely contributed to an expanded sink capacity through adequate availability of nitrogen at sensitive stages and subsequently led to higher grain yields. Additionally, exceeding the recommended levels of phosphorus and potassium did not have a statistically significant impact on grain yield when the nitrogen level was held constant. However, when nano urea was applied during the panicle initiation stage in conjunction with the recommended fertilizer dose, it yielded results that were statistically comparable to higher nitrogen levels. The results were similar to the findings of Cheng *et al.* (2022) in rice; Samanta *et al.* (2022) in finger millet; Samui *et al.* (2022) and Sairam *et al.* (2023) in maize. Interestingly, the mean straw yield of rice was significantly higher with T_4 but registered statistically comparable results with T_9, T_8, T_6 and exhibited 10.79% significant superiority over T_3. The better performance of T_4 could be explained by the relatively higher levels of nitrogen, phosphorus and potassium availability in comparison to the other treatments. The increased nutrient availability might have contributed to enhance the quality and rigidity of the rice straw. Nevertheless, the improvement in straw quality and rigidity due to these factors was statistically insignificant when compared to treatments with sufficient nitrogen supply. These results corroborate the findings of Moharana *et al.* (2019) and Mohanta *et al.* (2021). The highest mean biological yield was recorded by T_9 and this result did not significantly differ from T_4 and T_8. In comparison with T_3 the former treatment showed significant superiority and recorded a 13.13% increment in the biological yield of rice. This might be attributed to the maximum grain and straw yield of rice. Among all the treatments the lowest mean grain yield, mean straw yield and mean biological yield of rice was recorded by the T_1 (control) treatment. Although there are numerical differences among the treatments concerning harvest index (%), however, they did not differ statistically. Similar findings were observed by Awan *et al.* (2011) in rice; and Panda *et al.* (2021) in finger millet.

Influence of nutrient levels, optical sensors and decision support tools on nitrogen uptake in grain and straw of rice

The data about nitrogen uptake in grain and straw of rice were significantly influenced by different fertilizer levels, portable optical sensors and decision support tools (Table 3). The uptake of any nutrient is mainly determined by yield and nutrient content in its dry matter. In this study, the treatment T_9 outperformed all other treatments by showing significantly higher nitrogen uptake in grain during the crop-growing season in 2021 and 2022. Notably, the performance

Table 1: Details of fertilizer application during the period of investigation.

Treatment no.	Treatments*	Year	N application schedule
T_1	Absolute control	2021. 2022	NIL
T_2	90-45-45	2021. 2022	3 splits (45 kg/ha basal+22.5 kg/ha at AT**+22.5 kg/ha at PI**)
T_3	120-60-60	2021. 2022	3 splits (60 kg/ha basal+30 kg/ha at AT+30 kg/ha at PI)
T_4	150-75-75	2021. 2022	3 splits (75 kg/ha basal+37.5 kg/ha at AT+37.5 kg/ha at PI)
T_5	T_2 + NU @ 2 ml/L at PI	2021. 2022	3 splits (45 kg/ha basal+22.5 kg/ha at AT+22.5 kg/ha at PI) followed by foliar spray of nano urea (NU) at panicle initiation
T_6	T_3 + NU @ 2 ml/L at PI	2021. 2022	3 splits (60 kg/ha basal+30 kg/ha at AT+30 kg/ha at PI) followed by foliar spray of nano urea (NU) at panicle initiation
T_7	N application at LCC ≤3	2021	3 splits (33 kg/ha basal+33 kg/ha at 35 DAT**+33 kg/ha at 49 DAT
		2022	3 splits (33 kg/ha basal+33 kg/ha at 35 DAT+33 kg/ha at 56 DAT
T_8	N application at LCC ≤4	2021	4 splits (33 kg/ha basal+33 kg/ha at 21 DAT+33 kg/ha at 35 DAT+33 kg/ha at 49 DAT
		2022	4 splits (33 kg/ha basal+33 kg/ha at 28 DAT+33 kg/ha at 42 DAT+33 kg/ha at 56 DAT
T_9	N application at SI<90%	2021	4 splits (60 kg/ha basal+30 kg/ha at 28 DAT+30 kg/ha at 42 DAT+30 kg/ha at 63 DAT
		2022	4 splits (33 kg/ha basal+33 kg/ha at 21 DAT+33 kg/ha at 35 DAT+33 kg/ha at 56 DAT
T_{10}	Nutrient expert (TY**: 5.5 t/ha)	2021, 2022	3 splits (33 kg/ha basal+38 kg/ha at 15 DAT+38 kg/ha at 30 DAT)
T_{11}	Rice crop manager (TY: 5.5 t/ha)	2021	3 splits (35 kg/ha basal+40 kg/ha at 26 DAT+40 kg/ha at 43 DAT)
		2022	3 splits (35 kg/ha basal+40 kg/ha at 23 DAT+43 kg/ha at 41 DAT)

Note: The full dose of phosphorus and potassium fertilizers were applied as basal and the specified dosage in treatment T_3 was applied in treatments T_7, T_8, T_9.
**AT= Active tillering; PI= Panicle initiation; DAT= Days after transplanting; TY= Target yield.

of T_9 in terms of nitrogen uptake by rice grain was statistically equivalent to those of T_4, T_8 and T_6 during both the respective years of investigation 2021 and 2022. This superior performance might be attributed to the former treatment, through its grain yield and enhanced nitrogen concentration in the grain dry matter due to precise and consistent nitrogen supply at adequate levels of phosphorus and potassium through real-time monitoring of chlorophyll index at regular intervals. These findings corroborate with the findings of (Moharana *et al*., 2019; Baral *et al*., 2021).

However, it's worth mentioning that T_4 recorded the highest nitrogen uptake in rice straw in 2021 and 2022, respectively. Apart from T_9, T_8, T_6 and T_3, all other treatments under comparison exhibited a significant difference in nitrogen uptake by straw in 2021 with the former treatment while, T_9, T_8, T_6, T_{11} and T_3 showed statistical similarity but the remaining treatments exhibited significant difference in nitrogen uptake by straw in 2022. The absorption of nitrogen by rice straw was primarily determined by the quantity of straw produced and the nitrogen content left within the straw after contributing to grain production. These factors, in turn, were predominantly affected by the provision of an ideal amount of nitrogen without any restrictions on the availability of phosphorus and potassium. This discussion was in agreement with the findings of (Singh *et al*., 2015; Nandan *et al*., 2020 and Sreedevi *et al*., 2022).

Influence of nutrient levels, optical sensors and decision support tools on agronomic N efficiency and N recovery efficiency of rice

Among the treatments, the treatment T_8 was found to register the highest Agronomic efficiency and Recovery efficiency during both the years of investigation 2021 and 2022 (Table 4). Increase in grain yield in proportion to the nitrogen applied; likely be the probable reason for recording comparatively higher agronomic efficiency by

Table 2: Influence of different nutrient levels, portable optical sensors and decision support tools on yield and harvest index of rice (Mean of 2021 and 2022).

Treatments*	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
T_1	2681	3586	6267	42.78
T_2	3762	4579	8341	45.13
T_3	4603	5440	10042	45.80
T_4	5306	6027	11333	46.89
T_5	4268	4804	9072	46.77
T_6	4918	5617	10535	46.67
T_7	4385	4942	9327	47.02
T_8	5157	5917	11074	46.56
T_9	5379	5982	11361	47.22
T_{10}	4182	5236	9418	44.24
T_{11}	4474	5464	9938	45.06
SEm (±)	232	187	272	1.64
LSD (P=0.05)	690	555	809	NS

Table 3: Influence of different nutrient levels, portable optical sensors and decision support tools on nitrogen uptake in grain and straw of rice.

Treatments*	Nitrogen uptake (kg/ha)			
	Grain (kg/ha)		Straw (kg/ha)	
	2021	2022	2021	2022
T_1	36.27	36.08	19.14	18.80
T_2	54.21	57.48	24.21	27.69
T_3	69.82	73.66	30.08	33.81
T_4	81.07	87.00	34.39	39.76
T_5	61.61	65.87	25.60	29.39
T_6	74.64	79.22	31.89	35.27
T_7	64.93	68.69	27.36	29.93
T_8	78.74	83.95	33.79	37.26
T_9	82.22	88.44	34.13	37.95
T_{10}	60.97	63.98	28.83	32.37
T_{11}	67.70	70.88	30.46	34.02
SEm (±)	3.78	3.96	1.84	2.04
LSD (P=0.05)	11.24	11.76	5.46	6.06

Table 4: Influence of different nutrient levels, portable optical sensors and decision support tools on Agronomic N efficiency and N recovery efficiency of rice.

Treatments*	Nitrogen use efficiency (NUE)			
	Agronomic efficiency (kg grain/kg N applied)		Recovery efficiency (%)	
	2021	2022	2021	2022
T_1	-	-	-	-
T_2	11.36	12.66	25.57	33.65
T_3	15.48	16.55	37.08	43.83
T_4	17.04	17.96	40.03	47.92
T_5	12.70	12.68	26.50	33.65
T_6	13.54	14.41	31.95	37.25
T_7	16.61	17.80	37.25	44.18
T_8	18.22	19.29	43.27	50.25
T_9	17.47	18.50	40.63	47.67
T_{10}	13.35	14.20	31.55	38.04
T_{11}	15.32	15.83	38.17	44.66

the former treatment such that for each kilogram application of nitrogen the grain yield was found to be increased by 18.22 kg in 2021 and 19.29 kg in 2022 over no fertilizer control. Likewise, the greater increase in total nitrogen uptake in proportion to the nitrogen applied may be the contributing factor for the elevated recovery efficiency and in the former treatment, it was found that only 43.27% and 50.25% shall be recovered from the total N fertilizer applied during 2021 and 2022, respectively. Similarly, Subedi *et al.* (2018), Baral *et al.* (2021) in rice reported significantly higher agronomic nitrogen use efficiency and recovery efficiency.

CONCLUSION

The research recommends using nitrogen application when the leaf colour chart (LCC) is equal to or less than 4, in combination with the recommended levels of phosphorus and potassium. This approach is statistically comparable to the treatment that excels in grain yield, as it requires comparatively less nitrogen input, resulting in higher nitrogen use efficiency compared to other treatments. Consequently, deemed to contribute towards the pursuit of sustainability.

Conflict of interest

Authors do not have any conflict of interest.

REFERENCES

Anonymous, (2023a), Agricultural Statistics at a Glance 2022. Department of Agriculture and Farmers Welfare Economics and Statistics Division, Government of India. pp. 28.

Anonymous, (2023b), Agricultural Statistics at a Glance 2022. Department of Agriculture and Farmers Welfare Economics and Statistics Division, Government of India. pp. 29.

Awan, T.H., Ali, R.I., Manzoor, Z., Ahmad, M., Akhtar, M. (2011). Effect of different nitrogen levels and row spacing on the performance of newly evolved medium grain rice variety KSK-133. Journal of Animal and Plant Sciences. 21: 231-234.

Baral, B.R., Pande, K.R., Gaihre, Y.K., Baral, K.R., Sah, S.K., Thapa, Y.B., Singh, U. (2021). Real-time nitrogen management using decision support-tools increases nitrogen use efficiency of rice. Nutrient Cycling in Agroecosystems. 119: 355-368.

Cheng, F., Bin, S., Iqbal, A., He, L., Wei, S., Zheng, H., Yuan, P., Liang, H., Ali, I. Xie, D., Yang, X., Xu, A. Ullah, S., Jiang, L. (2022). High sink capacity improves rice grain yield by promoting nitrogen and dry matter accumulation. Agronomy. 12: 1688. https://doi.org/10.3390/agronomy12071688.

Chivenge, P., Sharma, S., Bunquin, M.A., Hellin, J. (2021). Improving nitrogen use efficiency-A key for sustainable rice production systems. Frontiers in Sustainable Food Systems. 5: 737412. https://doi.org/10.3389/fsufs.2021.737412.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedure for Agricultural Research (2nd Edn.). John Wiley and Sons, New York. pp. 25.

Keerthi, M.M., Srivastav, P., Rajasekar, G., Arun, A., Babu, R. (2023). Precision nitrogen management in aerobic system for maximising paddy (*Oryza sativa* L.) yields: A review. Crop Research. 58: 107-115.

Li, M., Zhang, H., Yang, X., Ge, M., Ma, Q., Wei, H., Dai, Q., Huo, Z., Xu, K., Luo, D. (2014). Accumulation and utilization of nitrogen, phosphorus and potassium of irrigated rice cultivars with high productivities and high N use efficiencies. Field Crops Research. 161: 55-63.

Mohanta, S., Banerjee, M., Malik, G.C., Shankar, T., Maitra, S., Ismail, I.A., Dessoky, E.S., Attia, A.O., Hossain, A. (2021). Productivity and profitability of *kharif* rice are influenced by crop establishment methods and nitrogen management in the lateritic belt of the subtropical region. Agronomy. 11: 1280. https://doi.org/10.3390/agronomy11071280.

Moharana, S., Gulati, J.M.L., Pradhan, S. (2019). Nutrient uptake and nitrogen use efficiency of rice genotypes under LCC-based N application during summer. Agricultural Science Digest. 39: 59-62.

Nandan, N., Roy, D.K., Kumar, S., Kumar, A. (2020). Effect of nitrogen on growth, yield and nutrient uptake of rice under aerobic condition. International Journal of Current Microbiology and Applied Sciences. 9: 2025-2035.

Panda, P., Maitra, S., Panda, S.K., Shankar, T., Adhikary, R., Sairam, M., Gaikwad, D.J. (2021). Influence of nutrient levels on productivity and nutrient uptake by finger millet [*Eleusine coracana* (L.) Gaertn] varieties. Crop Research. 56: 128-134.

Sairam, M., Maitra, S., Sagar, L., Krishna, T.G., Sahoo, U. (2023). Precision nutrient management on the growth and productivity of *rabi* maize (*Zea mays* L.) under light textured brown forest soils of Odisha. Research on Crops. 24: 487-495.

Samanta, S., Maitra, S., Shankar, T., Gaikwad, D., Sagar, L., Panda, M., Samui, S. (2022). Comparative performance of foliar application of urea and nano urea on finger millet [*Eleusine coracana* (L.) Gaertn]. Crop Research. 57: 166-170.

Samui, S., Sagar, L., Sankar, T., Manohar, A., Adhikary, R., Maitra, S., Praharaj, S. (2022). Growth and productivity of *rabi* maize as influenced by foliar application of urea and nano-urea. Crop Research. 57: 136-140.

Singh, F., Kang, J.S., Singh, A., Singh, T. (2015). Nutrient uptake, nutrient availability and quality parameters of mechanically transplanted rice (*Oryza sativa* L.) under split doses of nitrogen. Agricultural Science Digest. 35: 95-100.

Singh, V., Kunal, Kaur, J., Bhatt, R., Kaur, S., Dhillon, B.S., Singh, K.B., Singh, S., Sharma, S., Singh, B. (2023). Site-specific fertilizer nitrogen management in less and high N responsive basmati rice varieties using newly developed PAU-leaf colour chart. Communications in Soil Science and Plant Analysis. 54: 1334-1349.

Sreedevi, B., Singh, A., Ram, T., Singh, S., Srivastava, A.K., Singh, U.S., Kumar, R.M. (2022). Assessing the performance of drought-tolerant rice varieties under varied nitrogen doses. Current Journal of Applied Science and Technology. 41: 21-35.

Subedi, P., Sah, S.K., Marahattha, S., Panta, S., Shrestha, J. (2018). Nitrogen use efficiency in dry direct seeded rice under LCC based nitrogen management. Oryza-An International Journal on Rice. 55: 590-595.

Swamy, G.V.V.S.N., Shankar, T., Maitra, S., Adhikary, R., Praharaj, S., Sairam, M. (2022). Influence of nitrogen management on productivity, nutrient uptake and efficiency of summer maize (*Zea mays* L.). Research on Crops. 23: 313-320.