Indian Farmer
Volume 11, Issue 12, 2024, Pp. 526-535
Available online at: www.indianfarmer.net
ISSN: 2394-1227 (Online)

Original article

OPEN ACCESS

Site specific Nutrient management in Rice: Special reference to Odisha

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Received: 02/12/2024 *Published:05/12/2024*

ABSTRACT

Rice, the staple crop for millions, is vital for food security, particularly in regions like Odisha, where it spans 4 million hectares with a productivity of 2.3 t/ha. However, inefficient fertilizer use, poor soil health, and diverse agro-ecologies hinder productivity. Site-Specific Nutrient Management (SSNM) offers a solution by tailoring nutrient application to field-specific needs, optimizing the supply-demand balance of nutrients. Tools like Leaf Colour Chart, SPAD meter, Green Seeker, and decision-support systems like Nutrient Expert and Crop Manager improve nutrient use efficiency, resulting in higher yields (12-25% more than conventional) and reduced environmental impact. SSNM principles prioritize indigenous nutrient sources, precise application timing, and targeted rates. Studies demonstrate that SSNM significantly enhances rice yields, with tools like Green Seeker improving grain yield by 25% over control plots. By integrating the 4R principles—Right Source, Rate, Time, and Place—SSNM ensures sustainable productivity, profitability, and minimal environmental footprint, making it essential for precision agriculture in rice.

Keywords: SSNM, SPAD, Green Seeker, Omission plot and Yield

INTRODUCTION

Rice is a staple crop and a major source of livelihood for millions of people worldwide. The Asia-Pacific Region produces and consumes almost 90% of the world's rice. Seventy-five percent of the rice produced in Asia is produced on irrigated land, according to FAO. It is the most widely cultivated crop in India taking up more than 46 million hectares of land with a productivity of 2.8 t/ha while in Odisha it takes up about 4 million hectares with a productivity of 2.3 t/ha. In 2019 our population was 1.3 billion which has sharply increased to 1.4 billion. During this time the increase in production was 116.4 MT to 132 MT. The per capita net availability also increased from 186.3 g/day in 2019 to 226.5 g/day in 2023 (Anonymous, 2023). But this is not sufficient to meet the ever-increasing demand of the people of India as productivity is lower than world's average productivity with the reasons being varied agro-ecologies in both irrigated and rainfed systems, improper application of fertilizers and poor soil health. States like Odisha, West Bengal, Jharkhand and Chhattisgarh have

huge potential for rice cultivation and there is scope to increase productivity in this region (Kumar & Sharma, 2023).

One of the many reasons for such for low productivity in rice is the low nutrient efficiency which is due to nutrient loss(volatilization, denitrification, erosion, leaching and runoff), soil fixation of nutrients (P in deficient, highly weathered acid soils, K in highly illitic clay soils and Zn in high clay and calcareous soils), antagonistic interactions among certain nutrients (P and Zn, Na and K, Mg and K), imbalanced use of a few straight fertilizers which results in reduced efficiency and problematic soils (acidity, salinity, alkalinity, etc.). Also nitrogen fertilizer recovery is around 25-40% while that of phosphorus is 15-25% for rice which has created an interest towards site-specific nutrient management.

Site Specific Nutrient Management (SSNM)

Crop productivity is greatly influenced by availability of nutrients. Traditional blanket fertilizer application practices often lead to inefficient fertilizer use, nutrient imbalances, and environmental degradation. This necessitated the use of SSNM to enable adjustment in fertilizer management for spatial and temporal variability. SSNM aims at dynamic field-specific management of N, P, and K fertilizer to optimize the balance between supply and demand of nutrients. The plants need for N, P, or K fertilizer are determined from the gap between the supply of a nutrient from indigenous sources as measured with a nutrient omission plot, and the demand of the rice crop for that nutrient, as estimated from the total nutrient required by the crop to achieve a yield target for average climatic conditions (Mannade *et al.*, 2019). SSNM is a plant-based approach which enables rice farmers to optimally supply their crop with essential nutrients. The optimal supply of nutrients for rice can vary from field-to-field depending on crop and soil management, historical use of fertilizers, management of crop residues and organic materials, and crop cultivar. Hence, the SSNM approach provides the principles and guidelines for tailoring nutrient management practices to specific field conditions (Buresh R.J., 2007). It is an alternative approach for dynamic management of nutrients to optimize supply and demand of a nutrient within a specific field in a particular cropping season. (Dobermann *et al*., 2004). It provides a pattern for splitting the estimated N fertilizer requirement among pre-set application times & for fertilizers P & K recommendations are based on the indigenous supply of these nutrients from soil, organic materials and irrigation water considering nutrient removal with grain and straw. It was developed by IRRI for rice cultivation in Asia.

Over the years various researches were conducted where it was observed that high yielding rice varieties has maximum yield of 10 t/ha in the dry season and 7-8 t/ha in wet season. While the attainable yields with the best management practice is about 75-80% of climatic yield, depending on the environment. On the contrary farmers achieve only less than 60% of climatic and genetic yield potential at a particular site which is 20% less than the highest realizable yields. So, site specific nutrient management takes into account nutrient requirements of the crops and cropping systems, soil capacity to supply nutrients, productive capacity of the varieties under best crop management strategies with improved nutrient use efficiency and at the same time maintain environmental quality to achieve targeted yield for the given site.

Principles and Approaches to site specific nutrient management

1) SSNM provides an approach for feeding crops with nutrients as and when needed.
2) Optimal use of existing indigenous nutrient sources, including crop residues and manures.
3) Timely application of fertilizers at optimal rates to meet the deficit between the nutrient needs of a high yielding crop and the indigenous nutrient supply.

In Odisha a single field is usually 0.2-1 ha in size which offer immense opportunity for site specific nutrient management. The approaches to SSNM involves 3 steps –

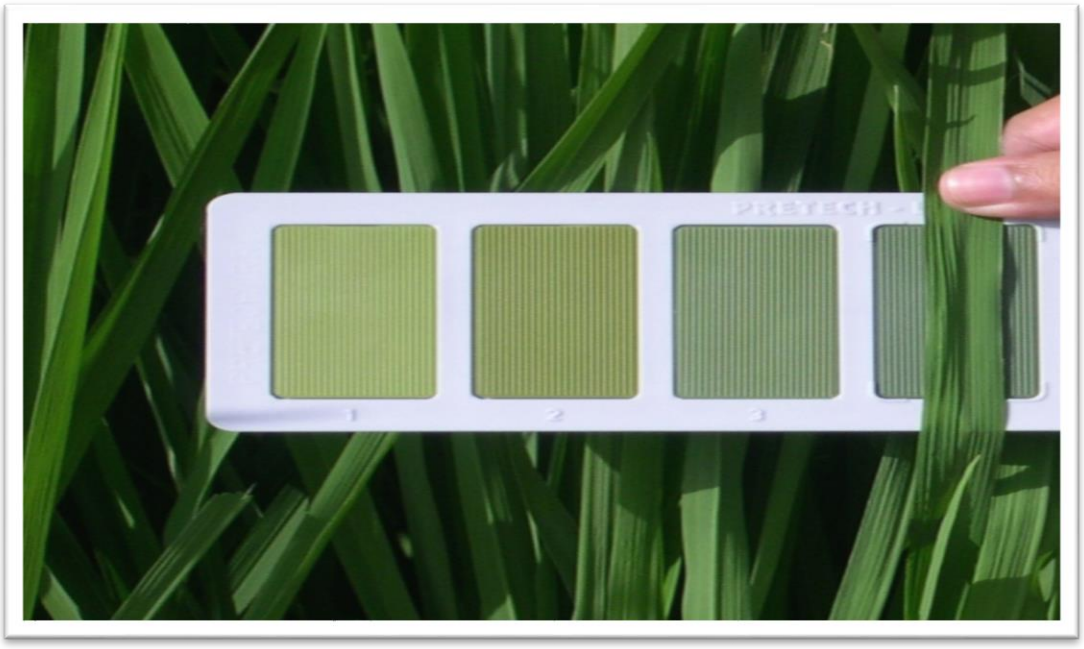
1. Establishing a target yield and estimating the total nutrients the crop requires to achieve it.
2. Effectively use existing nutrients, i.e, supplied from indigenous source such as soil, crop residue, manure and irrigation water.
3. Fill the deficit between total needs and indigenous supply. (Anonymous, 2023)

Nutrient Management in Rice

In rice phosphorus and potassium are given as basal dose while nitrogen is given in split dosage. In certain cases where soil is sandy in nature potassium can be given in 2 splits. The nitrogen is basically given in 3 splits based on nitrogen that is needed by crop after indigenous supply is identified. Fertilizer application is mostly done after proper soil test and other measurement techniques applied in SSNM. This method allows for more accurate and effective fertilizer administration.

Tools used in Site Specific Nutrient Management

1. **Leaf Colour Chart:** Leaf colour chart (LCC) is used for real-time N management in rice. It is a plastic, ruler shaped strip that range in colour from yellowish green to dark green. This saves nearly 26% nitrogen fertilizer. It has a critical value of 4.



2. **SPAD meter:** It provides a simple, quick & non-destructive method for estimating leaf chlorophyll content as it is closely correlated with leaf N concentration. It also indicates nitrogen deficiency in rice plant.

3. **Green Seeker:** Green Seeker is an integrated optical sensing and application system that offers a more efficient and accurate way to apply fertilizer immediately. It is an affordable and innovative diagnostic tool for assessing crop vigour. As Green Seeker takes care of both spatial and temporal variability, fertilizer use efficiency can be improved.

Table 1: Yield Attributes, Yield and Economics of Rice as Influenced by Site Specific Nutrient Management

Sl. No.	Treatments	Plant height(cm)	No. of Tillers per m²	Grain yield(t/ha)	Straw yield(t/ha)	HI(%)	Cost of Cultivation(₹/ha)	Net Return(₹/ha)	B:C
T1	RDF	121.2	295	4.59	5.65	44.8	67979	32270.3	1.48
T2	LCC BN-0	123.7	298	4.85	5.83	45.4	67873	37769.8	1.56
T3	LCC BN-20	124.5	316	**5.15**	6.27	45.1	68315	44135.3	1.65
T4	SPAD BN-0	121.6	305	4.94	5.83	45.9	68445	39050.8	1.57
T5	SPAD BN-20	125.2	366	**5.52**	6.45	46.1	68601	51280.3	1.75
T6	GS BN-0	124.4	310	4.99	6.01	45.4	68004	40812.3	1.6
T7	GS BN-20	126	381	**5.74**	6.57	46.7	68601	55982.3	1.82
T8	N-150	129.8	278	4.33	6.36	40.5	68892	27723.1	1.41
T9	N-0	107.4	248	2.87	4.27	37.8	66313	-7527.3	0.89
T10	STBN	123.2	326	4.99	6.08	45.1	68240	40629.3	1.6
T11	INM	124.7	332	5.31	6.29	45.8	70531	44955.9	1.64
T12	ORGANIC	117.1	271	3.83	5.35	43	84020	4852	0.97
	MEAN	122.4	311	4.76	5.91	44.3	69651	34328	1.5
	SEm (±)	0.26	1.16	0.11	0.06	0.28	87.6	81.6	0.015
	CD (0.05)	0.77	3.6	0.34	0.17	0.83	272.6	239.1	0.045

T1 - RDF (N_2:P_2O_5:K_2O::80:40:40 kg ha^{-1}), T2 - 20 Kg N ha^{-1} at LCC score <4 with no basal N, T3 - 20 Kg N ha^{-1} at LCC score <4 with 20 Kg N ha^{-1} at basal, T4 - 20 Kg N ha^{-1} at SPAD value <35 with no basal N, T5- 20 Kg N ha^{-1} at SPAD value <35 with 20 Kg N ha^{-1} at basal, T6- 20 Kg N ha^{-1} at Green seeker (GS) >1.25 RI with no basal N, T7- 20 Kg N ha^{-1} at Green seeker (GS) >1.25 RI with 20 Kg N ha^{-1} at basal, T8- 150 Kg N ha^{-1}(Sufficient level of N2), T9- nitrogen omission plot, T10- STBN (N2:P2O5:K2O::100:40:40 kg ha-1), T11- integrated nutrient management (20 Kg N as FYM at basal + 40 Kg N at tillering + 20 kg N at PI stage) and T12- organic nutrient management (FYM 10t ha^{-1} at basal + 2t ha^{-1} VC top dressing). (**Source:** Sahoo *et al.*, 2022)

In rice cultivation nitrogen application through green seeker was found to register higher productivity in comparison to normal blanket application due to efficient use of nitrogen which reflected in the increase in growth and yield attributes as shown in above table.

The above table also shows how use of different tools for site specific nutrient management affect the yield of rice. When fertilizers were applied in accordance with the recommendations by LCC, SPAD meter & Green seeker it was found that the yield obtained was higher in comparison to soil test-based fertilizer application. It was observed that under SSNM based approaches there was

12% increment in yield under LCC while there was an increment of 20% and 25% under SPAD and Green seeker respectively as compared to RDF (T1).

4. **Soil Test Crop Response (STCR):** The soil test crop response (STCR) approach for targeted yield is unique in indicating both soil test-based fertilizer dose and the level of yield that can be achieved with good management practices. In order to sustain the yield and reduce the cost of fertilizers and in turn cost of cultivation, the STCR approach is very important.

   STCR equation for recommend N, P, K fertilizers for rice-

   F N= 4.39T – 0.6723 SN

   F P_2O_5 = 2.83T – 6.110 SP

   F K_2O = 1.41T- 0.329 SK

   F N, P_2O_5, K_2O is fertilizers to be applied (Kg/ha)

   T is target yield (Quintal /ha)

   S is N, P_2O_5, K_2O is soil supply nutrients (Kg/ha)

Table 2: Effect of fertilizer application practice on yield of rice

Approach	Fertilizer dose (Kg/ha)			Grain yield (Kg/ha)
	N	P_2O_5	K_2O	
No fertilizer	0	0	0	948
Blanket recommendation	115	75	35	4594
STCR fertilizers	193	77	37	5861

(**Source:** Raman K. V. *et al.*, 1979**)**

The above table depicts how application of fertilizers based on STCR yields far better results as compared to blanket recommendation and no fertilizer application. It was observed that there was an 27% increase in yield with respect to blanket application and 518% increase in yield with regards to no fertilizer application.

Table 3: Effect of different treatment on grain and straw yields of rice

Treatments	Rice Yield (t/ha)	
	Grain	Straw
T1(Control-No fertilizer)	2.05	4.62
T2(GRD)	4.48	6.4
T3(STCR RD for Target Yield 4t/ha)	4.33	6.28

T4(STCR RD for Target Yield 5.5t/ha)	5.05	9.05
T5(STCR for Target Yield + 5t/ha FYM for Target Yield 4t/ha)	4.93	8.1
T6(STCR for Target Yield + 5t/ha FYM for Target Yield 5.5t/ha)	5.83	9.13
S.E.m ±	0.16	0.36
CD(P=0.05)	0.5	1.08

(**Source:** Srivastava *et al*., 2016)

This table indicates the use of STCR recommended dose to attain various target yields in rice. It was observed that under T6(STCR for Target Yield + 5t/ha FYM for Target Yield 5.5t/ha) highest grain and straw yield was recorded as compared to control. This showcased that when fertilizers were provided according to STCR for a specified target yield there is higher fertilizer use efficiency resulting in better productivity. It was observed that there was 184% increase in yield in T6 as compared to T1.

5. **Emission plot technique:** The omission plot technique is used to estimate fertilizer requirements. In an omission plot, adequate amounts of all nutrients are applied except for the nutrient of interest (the omitted nutrient). The yield in such an omission plot is related to the indigenous soil supplying capacity of the omitted nutrient. The yield gap between a target yield and the yield in the omission plot is then used to calculate fertilizer requirements.

Table 4: Effect of omission plot technique on grain yield of rice

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
T1 (100% N P K Zn S)	4.97^{a}	7.50^{a}	12.5^{a}	39.9
T2 (-N)	3.15^{d}	5.12^{cd}	8.3^{cd}	38
T3 (-P)	3.93^{c}	6.27^{bc}	10.2^{b}	38.5
T4 (-K)	4.00^{bc}	5.95^{bc}	9.9^{bc}	40.3
T5 (-Zn)	4.74^{ab}	7.13^{ab}	11.9^{ab}	39.9
T6 (-S)	4.68^{abc}	7.04^{ab}	11.7^{ab}	40
T7 Control	2.20^{e}	4.10^{d}	6.3^{d}	35.6
S. E.m ±	0.18	0.4	0.44	2.04
C. D. (P=0.05)	0.5	1.2	1.3	NS

(**Source:** Majumdar *et al.,* 2023)

In the above table, it can be noticed that the treatment T5 was found at par with the best treatment, T1, which receives all the nutrients. This clearly states that even without Zn, a similar close yield can be achieved. If we consider the cost, so definitely the cost will be less in T5 compared to T1, but T5 produced a statistically at-par grain yield.

Nutrient Expert: It is computer-based decision support tool developed by International Plant Nutrition Institute (IPNI) that estimates the attainable yield for a farmer's field. It is based on the approach of feeding crops as and when necessary. This reduces in over and under fertilization of rice crop. It helps in determining the nutrient application rates based on estimated attainable yield and yield responses to fertilizer, considering the effect of climate, soil type and farmer's management practices (Amgain *et al.,* 2021). Various researches also showed that fertilizer application based on nutrient expert improved productivity as compared to local farmer's practice because of optimized rice source-sink relationship.

6. **Crop Manager:** It is a computer and mobile phone-based application developed by International Rice Research Institute (IRRI) which allows farmers to adjust nutrient application to crop needs based on soil characteristics, water management, and crop variety on their farm through the internet or text messages. It also addresses other constraints that limit rice yield and farmer's profit. These constraints can vary across areas, growing conditions, varieties and climate scenarios. Here trained extension workers interview farmers using the crop manager application and their responses are recorded to generate unique recommendation for their specific plots. These recommendations include advisories on source, timing and amount of fertilizers selected by farmers, crop cycle, weed management, organic fertilizer and nursery preparation.

Major Concept of Site-Specific Nutrient Management (4R concept)

This concept serves to guide farmers to the management practices that help keep nutrients on and in the field. The 4R's stand for right source, right rate, right time, and right place.

- Right Source: Selection of right source from which fertilizers are to be obtained is based on the assessment of which nutrients are required. It is common for farmers to focus their fertilizer source decision on a single nutrient which is in greatest need at the exclusion of other nutrients. This often comes from experience in seeing demonstration plots showing crop response to N. However, the maximum value obtained from N only comes if other macro, secondary and in some cases micronutrients are addressed.
- Right Rate: Under or over application of nutrients possess a major challenge to agriculture production in most parts of the developing world. The right rate of fertilizer application is essential to attain optimal yields. Soil testing has traditionally been the most commonly recommended means of assessing fertilizer rates.
- Right Time: The optimum timing of nutrient application to crops ensures their adequate supply during peak uptake and critical growth stages. Timing also plays a major role in reducing the loss of nutrients into the environment by ensuring a supply when crop demand is high.
- Right Place: Fertilizer placement can play a major role in nutrient uptake, especially with immobile nutrients and in those soils with a capacity to fix nutrients. So for nutrients like P, where early

season access to the nutrients is critical for cereal crop growth, placement in or near the seed row can have a major impact on crop response. Farm management practices also play a significant role in determining fertilizer placement (Johnston *et al.,*2014).

CONCLUSION

Site specific nutrient management (SSNM) is a new and useful concept. This concept is fundamental to precision nutrient applications in rice. It provides an approach for need based feeding of crops with nutrients. This makes the efficient utilization of nutrients, avoids the wastages of fertilizers and environmental footprints of chemical fertilizers are also reduced, crop yield increases while amount of nutrients applied mostly decrease. Farm profitability and NUE increase convincingly by using this novel concept.

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