Site Specific Nutrient Management for Increased Productivity and Nutrient Use Efficiency in a Rice- Rice Cropping System

RANI B.*, JACOB JOHN
*Department of Soil Science and Agricultural Chemistry, Kerala Agricultural University,
College of Agriculture, Vellayani, Kerala, INDIA

Abstract: A study was conducted at the Integrated Farming System Research Station, Karamana, Kerala, in a rice- rice cropping sequence during kharif and rabi seasons for five years to evaluate the effect of site specific nutrient management (SSNM) on wetland rice. The experiment was laid out in a randomized block design with the high yielding medium duration, red grained rice variety Uma. The treatments included three nutrient omission plots (N_0, P_0, and K_0) and five SSNM plots receiving different levels of N, P and K (N_1- 150 kg N ha^{-1}, P_1 to P_3 - 30, 60 and 90 kg P_2O_5 ha^{-1} and K_1 to K_3- 40, 80 and 120 kg K_2O ha^{-1}) along with Zn and S (20kg S ha^{-1} and 40 kg $ZnSO_4$ ha^{-1}) which were generally low in all the farmers fields, in addition to the state recommended dose of nutrients (SRDN) - 90:45:45 kg N: P_2O_5: K_2O ha^{-1} and farmers' fertilizer practice (FFP) - 90:22.5:22.5 kg N: P_2O_5: K_2O ha^{-1}. Two SSNM treatments receiving either S or Zn were also included to study their individual effects. Results revealed that the SSNM treatments generated a yield gain (system productivity) of 3.587t to 3.917t compared to the nitrogen omission treatment, and 1.665 t to 2.005 t compared to SRDN and 3.36 t to3.69 t compared to FFP. Skipping P or K continuously decreased rice yields significantly compared to the SSNM treatments but was better compared to FFP or state recommendation. The recovery efficiency of nutrients (RE) was higher for the SSNM treatments (N150, P30 to P90 and K40 to K120) than state recommendation or farmers' practice, but the physiological efficiency of nutrients remained comparable irrespective of the nutrient management practice or the level of applied nutrients. The agronomic efficiency showed an increase in the SSNM treatments but generally decreased with increasing levels of nutrient application.

Key words: Site specific nutrient management, rice productivity, nutrient use efficiency

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1. Introduction

Among the various cropping systems practiced in India, rice- rice cropping system is considered the most important owing to its area coverage and contribution to total food grain production. Increasing demand for rice necessitates enhanced production which is attainable by more efficient use of agricultural inputs, especially plant nutrients. Poor seed quality, low nutrient use efficiency, deteriorating soil fertility and stagnating productivity are the major concerns in rice production [11]. Rice is a heavy nutrient feeder and it's intensive cropping leads to large withdrawal of plant nutrients from the soil, thereby accentuating the problem of nutrient disorders and affecting crop yields [12].

Recent research have reaffirmed the limitations of fixed rate - fixed time fertilizer application for crops [13]. Due of the shortcomings of blanket recommendations which do not take into account the variability in soil nutrient supply and crop response to nutrients among different fields, the concept of site- specific nutrient management (SSNM) was developed for rice [3]. This approach enables rice farmers to supply the crop with optimum amount of required nutrients and to ensure that nutrient supply, is synchronized with crop needs at critical growth stages. Hence a study was conducted to maximize the attainable yield in a rice-rice cropping sequence by developing a suitable nutrient management package specific to a site for a rice- rice cropping system in Kerala involving more efficient use of nitrogen, phosphorus and potassium along with the addition of sulphur and zinc.

2. Materials and Methods

The materials used and the methods adopted in the research study is detailed hereunder.

2.1 Experimental site

The research was conducted at Integrated Farming System Research Station, Karamana, Thiruvananthapuram, Kerala under the Kerala Agricultural University. The area forms a part of 19.3 coastal ecosystem-hot humid-per humid region. The soil of the research farm belonged to the soil type of riverine alluvium with an acidic soil reaction. The soil was sandy clay loam in texture, low in N, S and Zn and medium in P and K status.

2.2 Experimental details

The study was carried out during kharif and rabi seasons for five years with the high yielding medium duration red grained rice variety Uma, to evaluate the performance of SSNM in a rice-rice cropping system.

The experiment was laid out in a randomized block design with three replications and 12 treatments (Table 1.) which included three nutrient omission plots (N_0, P_0, and K_0) and five SSNM plots receiving different levels of N, P and K (N_1- 150 kg N ha^{-1}, P_1 to P_3 - 30, 60 and 90 kg P_2O_5 ha^{-1} and K_1 to K_3- 40, 80 and 120 kg K_2O ha^{-1}) along with Zn and S (20kg S ha^{-1} and 40 kg $ZnSO_4$ ha^{-1}) which were generally low in all the farmers fields, in addition to the state recommended dose of nutrients (SRDN) and farmers' fertilizer practice (FFP).

Two SSNM treatments receiving either S or Zn were also included to study their individual effects. Application of S and Zn were omitted during the rabi seasons. The NPK fertilizer requirements were supplied through urea (46 % N), rajphos (20 % P_2O_5) and muriate of potash (60 % K_2O) respectively.

Table 1 Treatment details

Tr. No.	Kharif	Rabi
1	$N_0 P_2 K_2$ SZn	$N_0 P_2 K_2$
2	$N_1P_0 K_2$ SZn	$N_1P_0 K_2$
3	$N_1P_1K_2$ SZn	$N_1P_1K_2$
4	$N_1P_2 K_2$ SZn	$N_1P_2 K_2$
5	$N_1P_3K_2$ SZn	$N_1P_3K_2$
6	$N_1P_2 K_0$ SZn	$N_1P_2 K_0$
7	$N_1P_2 K_1$SZn	$N_1P_2 K_1$
8	$N_1P_2 K_3$SZn	$N_1P_2 K_3$
9	$N_1P_2 K_2$ Zn	$N_1P_2 K_2$
10	$N_1P_2 K_2$ S	$N_1P_2 K_2$
11	SR*	SR
12	FP**	FP

* SR – State recommended dose of nutrients (90:45:45 kg N: P_2O_5: K_2O ha^{-1})
** FP – Farmer's Practice (90:22.5:22.5 kg N: P_2O_5: K_2O ha^{-1})

Biometric observations like plant height, total tillers per hill and productive tillers per hill were recorded. Grain and straw yield recorded per plot were expressed in kg ha^{-1}. Plant and soil samples for chemical analysis were collected at harvest stage, and oven dried at 70°C and were analysed using standard procedures for organic carbon, N, P and K and the nutrient uptakes were calculated. The data obtained were statistically analysed using analysis of variance (ANOVA) technique [2]. The performance indicators used for agronomic evaluation of the treatments were *i. recovery efficiency (RE)* of fertilizer N, P and K *viz.* the increase in plant nutrient uptake per unit fertilizer applied (kg plant nutrient kg^{-1} fertilizer); *ii. physiological efficiency (PE)* of fertilizer N, P and K ie. increase in grain yield per unit increase in plant nutrient uptake from fertilizer (kg grain yield kg^{-1} fertilizer) and *iii. agronomic efficiency (AE)* ie. kg grain produced per kg of fertilizer nutrient applied.

3. Results and Discussions

3.1 Plant height and number of tillers

The impact of treatments on biometric characters like plant height, total tillers per hill and productive tillers per hill during kharif and rabi seasons are presented in Table 2. It was observed that the nitrogen omission treatments resulted in stunted growth, and decreased the number of total and productive tillers per hill. The higher rate of application of nitrogen (150kg N ha^{-1}) in the SSNM treatments (T3, T4, T5, T7 and T8) compared to the state recommendation and the farmers practice, resulted in comparatively better plant growth and productive tillers.

Superior plant height under higher dose of nitrogen, phosphorus and potassium can be due to better nutrient availability and reduced interplant competition. Similar results were reported from other studies which affirm that plant height was significantly increased by site specific application of higher doses of N, P and K to rice [9]. Adequate supply of nitrogen, phosphorus and potassium is favorable for increasing the growth of plants [8]. SSNM also improves plant vegetative growth and dry matter production due to improved photosynthetic activity and better nutrient use efficiency [4]. The nitrogen omission plots, though supplemented with 20 kg sulphur and 40 kg $ZnSO_4$ per hectare, recorded shorter plants with pale green or yellowish leaves.

Table 2 Effect of site specific nutrient management on growth characters of rice

Treatment	Plant height (cm)		Total tillers per hill		Productive tillers per hill	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
T_1	99.1	86.2	9.2	9.00	7.8	8.4
T_2	101.0	92.6	9.7	11.50	8.1	10.6
T_3	101.7	94.9	10.3	10.50	8.0	9.4
T_4	100.3	92.8	10.6	10.05	8.7	8.9
T_5	103.1	92.0	9.8	10.45	8.6	9.2
T_6	103.5	91.9	10.1	9.55	8.6	8.9
T_7	101.8	93.9	10.4	10.65	8.5	9.9
T_8	100.3	91.1	9.6	8.85	8.3	9.5
T_9	101.8	92.8	11.1	9.70	9.0	9.0
T_{10}	104.5	90.8	10.3	9.35	8.5	8.7
T_{11}	100.0	90.6	10.0	10.70	8.2	9.4
T_{12}	99.2	88.0	9.4	10.35	8.3	8.3
CD (0.05%)	NS	NS	NS	NS	NS	NS

3.2 Yield and system productivity

The SSNM treatments produced higher yield in terms of grain system productivity (Table 3). The SSNM treatments gave significantly increased grain yields and system productivity when compared to N0 (T1), P0 (T2) K0 (T6), SR (T11) and FFP (T12). Productivity was lowest in the nitrogen omission plots (T1) which was on par with the yield obtained from FFP (T12). It was also noticed that yield reduction was more in kharif than in rabi for the N_0 plots. This was again reflected in the system productivity with more than 25 per cent reduction in grain yield when compared to T_8 (SSNM treatment). The SSNM treatments generated a yield gain (system productivity) of 3.587 t to 3.917 t compared to the nitrogen omission treatment. State recommendation (T11) and FFP (T12) also recorded significantly lower yield than the SSNM treatments.

Yield gain (system productivity) for the SSNM treatments was 1.665 t to 2.005 t compared to state recommendation and 3.36 t to 3.69 t compared to FFP. Skipping P or K continuously also decreased yields compared to the SSNM treatments but was better compared to FFP or state recommendation. This was due to the effect of the increased dosage of N application [7]. Soil P and K were also in the medium range throughout the experimental period which might be the reason for comparatively better yield for T2, which was also supplemented with S and Zn. It was also noticed that higher rate of N application was converted into economic yield in rice which gave a greater system productivity upto 11.7 t ha^{-1} per annum, for the SSNM treatment T8.

Table 3 Effect of site specific nutrient management on grain and straw yield (kg/ha) of a rice -rice cropping system (pooled mean of five years)

Treat ment No.	Nutrient levels	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
		Kharif	Rabi	System Productivity	Kharif	Rabi	System Productivity
1	$N_0P_2K_2$ SZn	4056	3765	7821	7697	4929	12626
2	$N_1P_0K_2$ SZn	5480	5144	10624	9853	5966	15818
3	$N_1P_1K_2$ SZn	6557	4869	11427	9573	4885	14458
4	$N_1P_2K_2$ SZn	6507	5058	11565	9899	6067	15966
5	$N_1P_3K_2$ SZn	6346	5061	11408	9653	6120	15774
6	$N_1P_2K_0$ SZn	5580	4932	10512	9444	5768	15213
7	$N_1P_2K_1$SZn	6480	5098	11578	9298	4872	14171
8	$N_1P_2K_3$SZn	6358	5381	11738	10136	6219	16356
9	$N_1P_2K_2$ Zn	5044	4599	9643	9430	5644	15074
10	$N_1P_2K_2$ S	4934	4442	9376	6579	5748	12327
11	SR	5021	4712	9733	8621	5482	14103
12	FFP	4227	3821	8048	8604	3808	12412
	CD (0.05)	811.4	647.9	1139.6	NS	1257.2	2444.6

The nutrients provided by SSNM had fulfilled the nutrient requirement of the rice crop thus resulting in better yield [5], [9] and thus substituting farmer's nutrient practices with SSNM can boost rice productivity attain maximum yields. The improved yield can be due to better nutrient status of the rice plant under SSNM and the resulting improvement in growth and yield attributes like better tillering, panicle production, grain filling etc. The positive effect of nutrients viz., N as a promoter of growth, P influencing better rooting and more nutrient uptake, K favouring better grain formation and increased filling percentage and supplementing Zn and S might have influenced the yield components ultimately leading to increased yields [6].

SSNM and it is evident that nutrient dose provided by SSNM-NE fulfills the nutrient requirement of crop when required hence better grain yield, straw yield, thousand grain weight, effective tillers. The treatments where site specific nutrient management approach was used, gave remarkably higher grain yield compared to treatments receiving fertilizer level as per State Recommendation of Kerala Agricultural University or those receiving nutrient doses as per farmers fertilizer practice. Withholding nitrogenous fertilizers, though with the addition of P and K resulted in the lowest economic yield or system productivity either in terms of grain or straw. These treatments also recorded significantly low system productivity compared to all other treatments. Treatments T_9 and T_{10}, where sulphur and zinc respectively were skipped, gave grain and straw yields on par with the treatment where state recommended dose of nutrients was applied.

The treatments receiving nutrients according to farmers practice recorded the second lowest system productivity. The farmers' fertilizer practice recorded more than 25 per cent reduction in grain yield or system productivity compared to the SSNM treatments. The treatment T2 and T6, where phosphorus and potassium fertilization respectively were skipped for the past five years also showed about 20 per cent reduction in grain yield. This confirms that continuous depletion of P and K leads to a marked reduction in grain yield compared to the SSNM treatment. Thus the concept of "feed the crop as needed" has been shown to increase the economic viability of rice farming for farmers [10].

3.3 Uptake of nutrients and efficiency of applied nutrients

In the nitrogen, phosphorus and potassium omission plots, the respective uptakes were significantly reduced during kharif season (Table 4).

Table 4 Effect of site specific nutrient management on the efficiency of applied nutrients (mean of five years)

Treatment	Total nutrient uptake (kg/ha)		Recovery efficiency		Physiological efficiency		Agronomic efficiency	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
a. Nitrogen								
N0	117.37	61.64	-	-	35	61	-	-
N150	180.99	91.05	0.42	0.20	36	55	16.34	8.6
SR	131.40	81.86	0.16	0.22	38	58	10.72	6.3
FFP	124.83	59.42	0.08	-0.02	34	64	1.90	0.6
b. Phosphorus								
P0	56.05	28.00	-	-	98	184	-	-
P30	61.00	27.70	0.16	-0.01	107	176	35.9	-9.2
P60	64.43	30.02	0.14	0.03	101	168	14.43	-1.5
P90	64.14	28.85	0.09	0.01	99	175	11.41	-0.9
SR	55.61	25.72	-0.01	-0.05	90	183	-10.2	-9.6
FFP	44.72	21.78	-0.50	-0.28	95	175	-55.69	-58.8
c. Potassium								
K0	231.61	126.13	-	-	24.00	39.00	-	-
K40	254.38	116.48	0.57	-0.059	25.00	44.00	22.5	4.15
K80	266.97	133.29	0.44	0.024	24.37	37.97	9.7	1.61
K120	261.89	129.09	0.25	-0.009	24.00	42.00	6.5	3.74
SR	224.65	118.18	-0.15	-0.054	22.00	40.00	-12.4	-4.89
FFP	245.03	86.58	0.60	-0.282	17.00	44.00	-60.1	-49.38

The recovery efficiency of nutrients (RE) was higher for the site specific nutrient management treatments (N150, P30 to P90 and K40 to K120) than SR or FFP (Table 4) especially for kharif season. Thus more of the applied nutrients are absorbed by the rice plant receiving site specific nutrient management practices. The recovery efficiency of SR and FFP was low since the plant is not able to absorb the applied nutrients efficiently and convert to plant dry matter or economic yield [1].

Though there is a remarkable variation in recovery efficiency among the treatments, the physiological efficiency of nutrients remained comparable irrespective of the nutrient management practice or the level of applied nutrients. This confirms that the ability of rice crop to convert the applied nutrient to economic yield depends on the amount of nutrients absorbed by the crop. The agronomic efficiency showed an increase in the site specific nutrient management treatments but generally decreased with increasing levels of nutrient application. Thus site specific nutrient management increases yield, nutrient recovery from applied fertilizer, physiological efficiency and agronomic efficiency of fertilizer nutrient compared to the farmers' fertilizer practice.

3.4 Soil nutrient status

The levels of soil available nutrients at the end of the experiment was found to be significantly less for the nitrogen, phosphorus and potassium omission treatments (Table 5) and also for the farmers' fertilizer practice especially during the kharif season. But soil organic carbon level was not affected by the different management practices during kharif and rabi at the end of the experimental period. During rabi season the effect of different treatments was not significant for available nitrogen and potassium also.

Table 5 Soil nutrient status as influenced by the treatments at the end of kharif and rabi seasons after five years

Treatment	Kharif				Rabi			
	Org C (%)	Avail N (kg ha^{-1})	Avail P (kg ha^{-1})	Exch. K (kg ha^{-1})	Org C (%)	Avail N (kg ha^{-1})	Avail P (kg ha^{-1})	Exch. K (kg ha^{-1})
T_1	0.81	236.80	19.16	206.64	0.82	177.18	12.38	114.52
T_2	0.91	282.23	13.09	155.68	0.78	210.10	12.91	121.52
T_3	0.86	282.23	15.25	190.40	0.79	172.45	12.41	123.48
T_4	0.80	275.98	17.31	164.64	0.78	186.58	13.19	130.48
T_5	0.81	254.05	17.09	199.64	0.86	205.40	15.13	107.52
T_6	1.03	243.05	17.91	143.36	0.84	166.20	13.22	118.16
T_7	0.84	290.08	19.38	166.88	0.83	172.48	13.56	119.84
T_8	0.93	257.15	15.84	190.96	0.84	191.28	13.03	132.44
T_9	0.88	250.90	17.28	162.96	0.75	211.65	13.66	109.48
T_{10}	0.93	257.18	17.88	143.76	0.78	185.00	13.94	130.20
T_{11}	0.80	260.28	18.91	168.28	0.78	191.30	12.91	125.16
T_{12}	0.82	265.00	15.06	123.20	0.79	175.60	10.63	138.32
CD(0.05%)	NS	22.725	1.605	30.94	NS	NS	1.817	NS

4. Conclusions

The higher rate of N application by site specific nutrient management was converted into economic yield of rice, increasing the system productivity to 10.5 - 12 t ha^{-1} per annum. Thus SSNM increases yield, profit, nutrient recovery from applied fertilizers and agronomic efficiencies of fertilizer nutrient compared to the state recommended dose of nutrients and farmers' fertilizer practice in a rice- rice cropping system.

References:

[1] Ashish Kumar Mannade, Dr. Anurag, Kanchan Bhandulkar and Balkrishnkanwar, Effect of site specific nutrient management on uptake and nutreint use efficiency of rice in vertisol. *International Journal of Chemical Studies*, 7(2), 2019,1021-1024.

[2] Cochran, W. G. and Cox, G. M. 1965. *Experimental Designs*. John Willey and Sons Inc., New York, 182p.

[3] Dobermann A. and White, P. F. (1999). Strategies for nutrient management in irrigated and rainfed lowland rice systems. *Nutr. Cycling Agroecosyst*. 53: 1-18

[4] Dobermann C. and A. Witt (2002). Site specific nutrient management approach for irrigated lowland rice in Asia Better Crops International, Vol 16 No.1.

[5] N. Fageria., 2010 “Yield Physiology of rice”, Journal of plant nutrition, Vol. 30(6), Pp. 843-879.

[6] Kalyanasundaram D., Harini Sri S., Vinodkumar S.R. and Senthilkumar K.P. (2020). Effect of site specific nutrient management on yirld characteristics and economics of transplanted rice in the Cauvery deltaic zone. *Plant Archives*Volume 20 No. 1, pp. 3154-3156

[7] Khurana, H.; Sidhu, A.; Singh, B. and Singh, Y. (2009). Performance of Site Specific Nutrient Management in a Rice- Wheat Cropping System. In The Proceedings of the International Plant Nutrition Colloquium XVI, Department of Plant Sciences, UC Davis.

[8] Pandey SN, Sinha B. N. (2006). Function of mineral nutrition in plant. Plant Physiology, Edn.4th, 120-139.

[9] Pant C., Joshi C., Gaire R. and Dahal B. (2020) Effect of Site Specific Nutrient Management Approach In Productivity Of Spring Rice In Kanchanpur, Nepal Malaysian Journal of halal research 3(1) p 24-30

[10] Peng, S., R.J. Buresh, J. Huang, X. Zhong, Y. Zou, J. Yang, G. Wang, Y. Liu, R. Hu, Q. Tang, K. Cui, F. Zhang and A. Dobermann (2010). Improving nitrogen fertilization in rice by site-specific N management. A review. Agron. Sustain. Dev., 30: 649–656.

[11] Tan PS, TQ Tuyen, TTN Huan, TQ Khuong, NT Hoai, CV Phung, LN Diep, HT Dung, NX Lai and A Dobermann. 2004. Site specific nutrient management in irrigated rice systems of the Mekong Delta of Vietnam. *In* Increasing productivity of intensive rice systems through site-specific nutrient management. Science publishers, Inc., and Intenational Rice Research Institute (IRRI) p.193-215.

[12] Tomar RK, Singh D, Gangwar KS, Garg RN, Gupta VK, Sahoo R. N. (2006). Influence of tillage systems and moisture regims on soil physical environment, growth and productivity of rice-wheat system in upper Gangatic plains of Western Uttar Pradesh. Indian Journal of Crop Science. 2006; 1(1):146-150

[13] Zhou W., L. Tengfei, Z. Yang, T. Wang, F. Yong, Y. Chen, R. Wanjun, 2017 Nature, Morphophysiological mechanism of rice yield increase in response to optimized nitrogen management.