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RESEARCH PAPER

Optimizing productivity of rice (*Oryza sativa* L.) through site specific nutrient management

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Abstract: An experimental study was conducted during *kharif* 2023 at the Agricultural Research Station, Mugad, to Optimise the productivity of rice through SSNM practices. The experiment was laid out with split-plot design included three replications with two rice varieties, Mugad Siri (M_1) and Mugad Sugandha (M_2), as the main plots and SSNM-based fertilizer rates as subplots. The sub plot treatment includes recommended Package of Practices (T_1), Soil Test Crop Response (T_2), Rice Crop Manager (T_3), Nutrient Expert (T_4) and an absolute control (T_5). The results showed that the RCM treatment significantly enhanced nutrient uptake (124.22 kg ha^{-1} N, 27.73 kg ha^{-1} P and 94.71 kg ha^{-1} K), yield attributes, achieving the highest grain yield (51.33 q ha^{-1}) and straw yield (71.25 q ha^{-1}), along with superior economic outcomes. Mugad Sugandha exhibited a higher grain yield (42.94 q ha^{-1}), test weight (22.06 g), panicle length (23.62 cm) and panicles per hill (13.17), while Mugad Siri had more grains per panicle (153.78), higher panicle weight (2.58 g) and straw yield (65.83 q ha^{-1}). RCM proved particularly effective for increasing grain yield and economic returns in Mugad Sugandha and for boosting straw yield in Mugad Siri.

Keywords: Nutrient expert, Nutrient uptake, Soil test crop response, Recommended Package of Practice, Rice crop manager

Introduction

Rice (*Oryza sativa* L.) is a vital staple food crop globally, with Asia accounting for over 90% of the world's rice production and consumption (Sun *et al*., 2022). As global demand for rice continues to rise, it is projected that by 2050, the requirement will reach approximately 584 million tons (Samal *et al*., 2022). However, the imbalanced application of fertilizers has led to soil degradation, reduced yields and significant losses for farmers, ultimately contributing to a decline in rice cultivation areas.

To enhance rice yield and improve economic returns, the adoption of Site-Specific Nutrient Management (SSNM) is crucial. SSNM is a precision agriculture strategy that tailors nutrient application to the specific needs of different areas within a field, rather than applying uniform rates across the entire field. By using SSNM techniques, fertilizers can be applied more effectively, addressing the unique nutrient requirements of each site.

Implementing SSNM has the potential to significantly increase the yield and profitability of transplanted rice, benefiting farmers by optimizing fertilizer use and improving soil health. This study focuses on assessing the impact of SSNM on the yield attributes, overall yield and economic outcomes of transplanted rice, demonstrating its effectiveness in promoting sustainable agricultural practices and enhancing farmers× livelihoods.

Material and methods

The experiment was conducted at the Agricultural Research Station (ARS), Mugad, during the *kharif* season of 2023. The study used a split-plot design with three replications, featuring two rice varieties—Mugad Siri (M_1) and Mugad Sugandha (M_2) as main plots, and various SSNM treatments as subplots. The treatments included: T_1 - Recommended Package of Practice (UASD), T_2 - Soil Test Crop Response (Basavaraja *et al*., 2016), T_3 - Rice Crop Manager (Anon, 2024), T_4 - Nutrient Expert (Anon, 2019) and T_5 - Absolute Control.

The experimental site had clay soil with a neutral pH, EC of 0.80 dS m^{-1}, low in available nitrogen and medium in phosphorus, potassium and sulphur. The soil contained sufficient levels of micronutrients. The fertilizer doses were worked out by formula for STCR and by using software for RCM and Nutrient Expert. Fertilizer doses for each treatment were as follows, T_1: 120 kg N, 50 kg P_2O_5, 50 kg K_2O, 20 kg $ZnSO_4$ per ha, plus 5 tons ha^{-1} FYM, T_2: 181.74 kg N, 79.73 kg P_2O_5, 4.00 kg K_2O per ha, plus 5 tons ha^{-1} FYM, T_3: 111.05 kg N, 31.05 kg P_2O_5, 39.00 kg K_2O, 25.00 kg $ZnSO_4$ per ha, plus 5 tons ha^{-1} FYM, T_4: 109.00 kg N, 25.00 kg P_2O_5, 49.00 kg K_2O er ha, plus 5 tons ha^{-1} FYM and T_5: Absolute Control. Yield parameters, grain and straw yield were recorded at harvest and nutrient uptake after harvest.

Results and discussion

SSNM influence on yield attributes and yield of transplanted rice

The study revealed no significant difference between the rice varieties Mugad Siri and Mugad Sugandha in terms of grains per panicle and panicle weight. However, Mugad Sugandha exhibited superior panicle length (23.62 cm), more panicles per hill (13.17) and a higher test weight (22.06 g), as shown in Table 1. Among the treatments, T_3 (RCM) resulted in the highest values for panicle length (22.63 cm), panicles per hill (14.00), grains per panicle (155.08), panicle weight (2.65 g) and test weight (20.28 g). The lowest values were observed in

Table 1. Yield and yield attributing parameters of Rice as influenced by site specific nutrient management

Treatments	Panicle length (cm)	Panicles per hill	Number of grains/ panicle	Panicle weight (g)	Test weight (g) (1000 grains weight)	Grain yield (q ha-1)	Straw yield (q ha-1)
Main plot (varieties)							
M_1	19.83	10.65	153.78	2.58	16.63	42.94	65.83
M_2	23.62	13.17	133.61	2.15	22.06	43.79	61.26
S.Em.±	0.89	0.48	0.22	0.07	0.17	0.56	0.45
C.D. at 5%	NS	NS	1.33	NS	1.03	NS	2.75
Sub plot (fertilizer recommendations)							
T_1	22.11	13.26	150.77	2.43	20.10	47.81	70.47
T_2	22.44	12.64	136.61	2.32	18.53	46.57	69.44
T_3	22.63	14.00	155.08	2.65	20.28	51.33	71.25
T_4	22.17	13.43	151.91	2.24	20.07	48.31	70.18
T_5	19.29	6.22	127.91	2.17	17.77	22.81	36.37
S.Em.±	1.55	0.33	2.37	0.08	0.41	0.60	1.05
C.D. at 5%	NS	0.98	7.10	0.24	1.23	1.78	3.15
Interactions							
M_1T_1	19.82	11.46	168.53	2.78	17.10	47.09	71.03
M_1T_2	20.57	10.88	141.22	2.63	16.16	45.89	70.16
M_1T_3	20.76	12.90	172.16	2.89	17.40	50.84	72.04
M_1T_4	20.30	12.27	168.50	2.37	17.30	47.52	71.18
M_1T_5	17.69	5.75	126.12	2.23	15.20	23.37	44.73
M_2T_1	24.40	15.06	133.00	2.09	23.10	48.52	69.91
M_2T_2	24.31	14.39	132.00	2.01	20.89	47.24	68.72
M_2T_3	24.49	15.09	138.00	2.41	23.15	51.82	70.46
M_2T_4	24.05	14.59	135.32	2.11	22.84	49.10	69.17
M_2T_5	20.88	6.70	129.71	2.12	20.34	22.26	28.01
S.Em.±	1.04	0.25	1.55	0.05	0.27	0.41	0.70
C.D. at 5%	NS	NS	NS	NS	1.33	1.70	2.31

Note: M_1: Mugadsiri, M_2: Mugadsugandha; T_1: RPP (as per UASD), T_2: Soil Test Crop Response, T_3: Rice Crop Manager, T_4: Nutrient Expert, T_5: control (No NPK, FYM),NS – No Significant difference

the control treatment (T_5), indicating that optimal fertilizer application in T_3 improved nutrient uptake, crop growth and yield attributes, consistent with the findings of Bhangare *et al.* (2023) and Kumar *et al.* (2023) which showed best results in treatment with optimum fertilizer application.The favorable soil conditions with higher nutrient availability due to precise and split application of nutrients resulted in higher yield and yield attributes. Sharanagouda *et al*, (2023) recorded higher growth and yield parameters in system of rice intensification with split application of nutrient in particular potassium.

In interactions, no significant differences were found for panicle length, panicles per hill, grains per panicle and panicle weight. However, test weight was significantly higher in M_2T_3 (23.14 g), while the lowest values were observed in M_2T_5.

In terms of yield, Mugad Siri demonstrated higher straw yield (65.83 q ha^{-1}) due to thicker straw, while T_3 (RCM) produced the highest grain yield (51.33 q ha^{-1}) and straw yield (71.25 q ha^{-1}). The superior yields in T_3 were attributed to optimal fertilizer use, as noted by Banayo *et al.* (2018), Kumar *et al.* (2023) and Sharma *et al.* (2019). The control treatment (T_5) produced the lowest grain and straw yields. Among interactions, M_2T_3 achieved the highest grain yield (51.82 q ha^{-1}), while M_1T_3 recorded the highest straw yield (72.04 q ha^{-1}). M_2T_5 consistently had the lowest yields.

Effect of SSNM on nutrient uptake of rice straw and grains

Mugad Siri exhibited higher total nitrogen uptake (103.97 kg ha^{-1}) and straw nitrogen uptake (45.16 kg ha^{-1}), followed by Mugad Sugandha. No significant difference in grain nitrogen uptake was observed, as shown in Table 3. Phosphorus and potassium uptakes in both grain and straw also showed no significant differences. The treatment, T_3 recorded significantly higher nitrogen and potassium uptake in straw (52.08 kg ha^{-1} and 78.37 kg ha^{-1}) and grains (72.13 kg ha^{-1} and 29.94 kg ha^{-1}), with the highest total uptake (124.22 kg ha^{-1} and 108.31 kg ha^{-1}, respectively). Conversely, T_5 exhibited the lowest uptakes. The treatment T_2 showed significantly higher phosphorus uptake in straw (7.91 kg ha^{-1}) and grains (16.47 kg ha^{-1}). Similar trends were noted by Shahi *et al.* (2022) and Tripathi *et al.* (2018).

The interaction, M_1T_3 recorded the highest nitrogen and potassium uptake in straw (54.47 kg ha^{-1} and 80.88 kg ha^{-1}), while M_2T_2 had the highest phosphorus uptake (8.64 kg ha^{-1}). In grains, M_2T_3 had the highest nitrogen (122.27 kg ha^{-1}), phosphorus (29.83 kg ha^{-1}) and potassium uptake (106.26 kg ha^{-1}).

Effect of SSNM on economics of rice cultivation

Mugad Sugandha had a higher cost of cultivation (₹ 54,845 ha^{-1}), while Mugad Siri had a slightly lower cost (₹ 54,657 ha^{-1}). The treatment, T_2 had the highest cost of cultivation

Table 2. Economics of rice as influenced by site specific nutrient management.

Treatments	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
Main plot (varieties)				
M_1	54657	137416	82759	2.49
M_2	54878	153260	98416	2.80
S.Em.±	-	1913	1913	0.03
C.D at 5%	-	11642	11642	0.19
Sub plot (fertilizer recommendations)				
T_1	57048	160260	103218	2.91
T_2	57594	156105	98511	2.71
T_3	55931	172034	116103	3.08
T_4	54594	161952	107357	2.97
T_5	48594	7634	27747	1.57
S.Em.±	-	1974	1974	0.06
C.D at 5%	-	5919	5919	0.18
Interactions				
M_1T_1	56948	150688	93740	2.65
M_1T_2	57500	146859	89359	2.55
M_1T_3	55837	162699	106861	2.91
M_1T_4	54500	152053	97553	2.79
M_1T_5	48500	74784	26284	1.54
M_2T_1	57136	169832	112696	3.18
M_2T_2	57688	165352	107664	2.87
M_2T_3	56025	181370	125345	3.24
M_2T_4	54688	171850	117162	3.14
M_2T_5	48687	77898	29211	1.60
S.Em.±	-	1381	1381	0.08
C.D at 5%	-	5717	5717	NS

Note: M_1: Mugadsiri, M_2: Mugadsugandha; T_1: RPP (as per UASD), T_2: Soil Test Crop Response, T_3: Rice Crop Manager, T_4: Nutrient Expert, T_5: control (No NPK, FYM), NS – No Significant difference

Table 3. Crop removal of primary nutrient as influenced by SSNM

Treatments	N (kg/ha)			P(kg/ha)			K (kg/ha)		
	Straw	Grain	Total	Straw	Grain	Total	Straw	Grain	Total
Main plot (varieties)									
M_1	45.64	58.33	103.97	5.91	14.63	20.51	59.28	22.04	81.33
M_2	41.15	59.02	100.17	6.68	15.37	22.12	57.96	22.37	80.41
S.Em.±	0.20	0.29	0.41	0.25	0.26	0.38	0.54	0.12	0.57
C.D. at 5%	1.22	NS	2.51	NS	NS	NS	NS	NS	NS
Sub plot (fertilizer recommendations)									
T_1	48.06	64.78	112.83	6.34	15.87	22.19	69.61	26.99	96.60
T_2	47.61	63.68	111.30	7.91	16.47	24.39	49.06	20.56	69.81
T_3	52.08	72.13	124.22	7.86	20.23	28.09	78.37	29.94	108.31
T_4	49.32	66.03	115.35	6.98	16.74	23.73	67.98	26.73	94.71
T_5	19.89	26.75	46.64	2.56	5.63	8.19	28.10	6.81	34.91
S. Em. ±	1.07	0.51	1.19	0.27	0.23	0.39	1.02	0.60	1.19
C.D at 5%	3.20	1.53	3.57	0.82	0.68	1.17	3.06	1.80	3.56
Interactions									
M_1T_1	49.02	64.21	113.23	6.16	15.56	21.68	67.97	26.98	94.95
M_1T_2	48.42	63.32	111.74	7.19	15.88	23.07	49.35	19.72	69.07
M_1T_3	54.47	71.69	126.17	6.95	19.47	26.35	80.88	29.48	110.36
M_1T_4	51.24	65.26	116.50	6.41	16.29	22.69	66.62	26.78	93.39
M_1T_5	25.04	27.17	52.21	2.84	5.94	8.77	31.60	7.26	38.86
M_2T_1	47.09	65.34	112.43	6.52	16.18	22.70	71.25	27.00	98.25
M_2T_2	46.81	64.05	110.86	8.64	17.06	25.70	48.76	21.39	70.55
M_2T_3	49.69	72.57	122.27	8.40	21.05	29.83	75.86	30.40	106.26
M_2T_4	47.41	66.79	114.20	7.56	17.20	24.76	69.35	26.68	96.03
M_2T_5	14.75	26.33	41.08	2.28	5.33	7.61	24.60	6.36	30.96
S. Em. ±	0.70	0.34	0.78	0.19	0.16	0.27	0.68	0.39	0.79
C.D at 5%	2.14	1.20	2.52	0.77	0.71	1.13	2.35	NS	2.67

Note: M_1: Mugadsiri, M_2: Mugadsugandha; T_1: RPP (as per UASD), T_2: Soil Test Crop Response, T_3: Rice Crop Manager, T_4: Nutrient Expert, T_5: control (No NPK, FYM), NS – No Significant difference

(₹ 57,594 ha^{-1}), attributed to the higher application of DAP and Urea, followed by T_1(₹ 57,042 ha^{-1}). The lowest cost of cultivation was recorded in T_5 (₹ 48,594 ha^{-1}). The interaction, M_2T_2 (Mugad Sugandha - STCR) had the highest cost of cultivation at ₹ 57,688 ha^{-1} due to the combined higher costs of seeds and fertilizers, followed by M_1T_2 (Mugad Siri - STCR) at ₹ 57,500 ha^{-1}. The lowest cost of cultivation (₹ 48,500 ha^{-1}) was recorded in M_1T_5 (Mugad Siri - Control) as shown in Table 2.

Mugad Sugandha demonstrated higher gross returns, net returns, and a B:C ratio of ₹ 153,260 ha^{-1}, ₹ 98,416 ha^{-1} and 2.80, respectively, due to its higher grain yield and market price, whereas Mugad Siri showed comparatively lower returns. The treatment, T_3 exhibited the highest gross returns at ₹ 172,034 ha^{-1}, net returns at ₹ 116,103 ha^{-1} and a B:C ratio of 3.08, driven by higher biological yields, followed by T_4. The lowest economic returns were noted in T_5. Similar trends were also observed by Adion and Cruz (2023), Kumar *et al*. (2019), Kumar *et al*. (2023) and Anand *et al*. (2017).

The interaction, M_2T_3 (Mugad Sugandha - RCM) achieved the highest gross returns at ₹ 181,370 ha^{-1}, net returns at ₹ 125,345 ha^{-1} and a B:C ratio of 3.24, due to its superior grain yield and market value as well as ideal nutrient supplements. The lowest economic performance was seen in M_1T_5 (Mugad Siri - Control).

Conclusion

The current fertilizer usage in irrigated low land rice fields tends to be too generalized, failing to account for site-specific yield potential and local soil fertility conditions. The existing approach calculates fertilizer requirements based on the total nutrient uptake needed to reach a target yield, the soil's nutrient-supplying capacity and the plant's ability to recover fertilizer nutrients under local conditions.

Mugad Sugandha demonstrated a higher test weight and more panicles per hill, leading to increased grain yield. This, in turn, resulted in higher gross returns, net returns, and a better benefit-to-cost (B:C) ratio compared to Mugad Siri. However, Mugad Siri produced a higher straw yield due to its thicker straw. Among all treatments, T_3 (Rice Crop Manager) achieved the highest grain and straw yields, driven by superior yield attributes compared to the other treatments. T_3 also recorded the highest gross returns, net returns and B:C ratio. The combination of Mugad Sugandha with Rice Crop Manager produced the best overall results in terms of grain yield, gross returns, net returns and B:C ratio.

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