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Poojitha K
Ph.D. Scholar, Department of Agronomy, College of Agriculture, GKVK, UAS, Bangalore, Karnataka, India

Lalitha BS
Professor, Department of Agronomy, College of Agriculture, GKVK, UAS, Bangalore, Karnataka, India

Jayadeva HM
Professor, Department of Agronomy, College of Agriculture, GKVK, UAS, Bangalore, Karnataka, India

Kadalli GG
Professor and Scheme Head, AICRP on LTFE, GKVK, UAS, Bangalore, Karnataka, India

Sujith GM
Professor, ARS, Balajigapade, UAS, Bangalore, Karnataka, India

Mohan Kumar TL
Assistant Professor, Department of Agricultural Statistics, Applied Mathematics and Computer Science, College of Agriculture, GKVK, UAS, Bangalore, Karnataka, India

Corresponding Author:
Poojitha K
Ph.D. Scholar, Department of Agronomy, College of Agriculture, GKVK, UAS, Bangalore, Karnataka, India

Response of aerobic rice to sunhemp seed rates and nitrogen levels under brown manuring: Nutrient uptake, nutrient use efficiency and economic returns

Poojitha K, Lalitha BS, Jayadeva HM, Kadalli GG, Sujith GM and Mohan Kumar TL

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Abstract
A field experiment was conducted during the summer and *kharif* seasons of 2023 at the Agronomy Field Unit, Zonal Agricultural Research Station, GKVK, UAS, Bangalore to evaluate the effect of different sunhemp seed rates and nitrogen management practices on nutrient uptake, nutrient use efficiency and economics of aerobic rice. The experiment consisted of three sunhemp seed rates (0, 50 and 75 kg ha^{-1}) and four nitrogen levels (0, 75, 100 and 125% of the recommended dose of nitrogen—RDN). Results revealed that sunhemp incorporation significantly enhanced nitrogen, phosphorus and potassium uptake in rice. Among the seed rates, 50 kg ha^{-1} of sunhemp recorded higher nutrient uptake (104.39, 28.24 and 97.16 kg ha^{-1} of N, P_2O_5 and K_2O, respectively), which was statistically on par with 75 kg ha^{-1}. Application of 125 per cent RDN resulted in significantly higher uptake (113.68, 30.75 and 105.63 kg ha^{-1} of N, P_2O_5 and K_2O, respectively). The interaction between sunhemp and nitrogen levels was significant, with the combination of 75 kg ha^{-1} sunhemp + 125 per cent RDN recording the higher nutrient uptake (116.34, 31.46 and 108.17 kg ha^{-1} of N, P_2O_5 and K_2O, respectively). Rice + sunhemp at 50 kg ha^{-1} recorded significantly higher phosphorus and potassium use efficiency (89.07 kg kg^{-1} each) and was on par with rice + sunhemp at 75 kg ha^{-1}. Among nitrogen levels, 125 per cent RDN produced the higher phosphorus and potassium use efficiency (102.61 kg kg^{-1} each). The combination of rice + sunhemp at 50 kg ha^{-1} with 125 per cent RDN recorded the maximum phosphorus and potassium use efficiency (106.08 kg kg^{-1} each). Economic analysis showed that the same combination of 50 kg ha^{-1} sunhemp + 125 per cent RDN yielded the higher gross returns (₹147,725 ha^{-1}), net returns (₹89,063 ha^{-1}) and benefit-cost ratio (2.52), confirming its superiority for aerobic rice cultivation.

Keywords: Aerobic rice, brown manuring, sunhemp, nitrogen and greengram

Introduction
Since the advent of agriculture, cereals have been the primary source of food for humans, largely because of their high carbohydrate content. Among these, rice (*Oryza sativa* L.) stands out as the most important cereal crop worldwide. It contributes about 21 per cent of the global per capita energy and 15 per cent of protein intake, making it a crucial part of the diet, particularly in Southeast Asian countries. Asia, home to 60 per cent of the world's population, produces nearly 92 per cent of the total global rice and accounts for 90 per cent of its consumption. Major producers such as India, China, Bangladesh, Indonesia, Thailand and Vietnam together supply almost three-fourths of the world's rice (Poornima, 2020) [10]. In India, rice serves as the staple food for more than 70 per cent of the population and plays a vital role in ensuring national food security while providing livelihoods to millions of households. The crop covers an area of about 47.83 million hectares, yielding 137.82 million tonnes with an average productivity of 2882 kg ha^{-1}. In Karnataka, rice is cultivated on around 9.53 lakh hectares, producing 31.27 lakh tonnes with an average productivity of 3282 kg ha^{-1} (Anon., 2024) [2].
However, challenges such as climate change, dwindling groundwater resources and labour shortages are threatening the sustainability of traditional rice cultivation systems. To address these issues, alternative production methods that conserve water and reduce labour dependency are necessary. One such approach is aerobic rice cultivation, which involves growing rice in

non-puddled, well-drained and aerated soils. This system requires significantly less water and is well-suited for direct-seeded practices. Despite these advantages, aerobic rice faces major weed problems, with potential yield losses ranging between 53 per cent and 90 per cent if weeds are not effectively controlled (Nyarko and De-Datta, 1991) [9].

Brown manuring has emerged as an eco-friendly strategy for weed suppression and soil fertility improvement in aerobic systems. The technique involves intercropping rice with green manure crops such as sunhemp or dhaincha, which are subsequently knocked down using a post-emergence herbicide like 2,4-D ethyl ester at around 25-30 days after sowing. The decomposed biomass enriches the soil with organic matter and nitrogen, enhances moisture retention and suppresses weed growth through shading and allelopathic effects (Tanwar *et al*., 2014) [13]. This practice can reduce the requirement for external nitrogen fertilizers by about 25 per cent and increase net farm income by up to 15 per cent. Nitrogen is a key nutrient in rice production as it promotes tillering, grain formation and protein accumulation. Nevertheless, the nitrogen use efficiency in rice remains relatively low due to losses through leaching, volatilization and runoff. In aerobic rice systems, the alternation between wet and dry soil conditions further complicates nutrient availability. Hence, optimizing the quantity of nitrogen application is essential for achieving sustainable productivity. Therefore, the experiment titled "Response of Aerobic Rice to Sunhemp Seed Rates and Nitrogen Levels under Brown Manuring: Nutrient Uptake, Nutrient Use Efficiency and Economic Returns" was carried out.

Materials and Methods

The field experiment was carried out during the summer and *kharif* seasons of 2023 at the Agronomy Field Unit, Zonal Agricultural Research Station, College of Agriculture, GKVK, University of Agricultural Sciences, Bangalore. The experimental site had red sandy loam soil, comprising 33.3% coarse sand, 31.6% fine sand, 6.9% silt and 28.2% clay. The soil reaction was neutral (pH 6.57), with low organic carbon (0.36%) and an electrical conductivity of 0.35 dS m^{-1}. It was low in available nitrogen (274.00 kg ha^{-1}), low in available phosphorus (15.80 kg ha^{-1}) and medium in available potassium (306.00 kg ha^{-1}).

The experiment was conducted with two different factors *viz.*, factor I: sunhemp seed rate (S_0 -Rice+ no sumnemp, S_1- Rice +sunhmep 50 kg ha^{-1} and S_2 -Rice + sunhemp 75 kg ha^{-1}) and factor II: RDN levels (N_0- 0 RDN, N_1 - 75% RDF, N_2 - 100% RDN and N_3 - 125% RDN). In total, 12 treatment combinations were evaluated using a factorial Randomized Complete Block Design (RCBD) with three replications. The rice variety KMP-175 was sown at a rate of 5 kg ha^{-1}, maintaining a spacing of 25 cm × 25 cm and a sowing depth of 4-5 cm. In the brown manuring treatments, sunhemp seeds were broadcasted simultaneously with rice sowing.

Nutrients were applied according to the treatment schedule using urea, single superphosphate and muriate of potash as sources of nitrogen, phosphorus and potassium, respectively. The recommended dose of fertilizer (RDF) was 100:50:50 kg $N:P_2O_5:K_2O$ ha^{-1}. Half of the nitrogen and the entire dose of phosphorus and potassium were applied as a basal dose at sowing, while the remaining 50 per cent nitrogen was top-dressed in two equal splits at 30 and 60 days after sowing (DAS). For brown manuring, plots were sprayed with 2,4-D ester @ 600 ml ha^{-1} at 25 DAS to desiccate sunhemp plants.

Observations on various growth and yield parameters were recorded from five randomly selected plants in each treatment plot at different growth stages. Yield data were collected at harvest. The recorded data were analyzed statistically using Fisher's method of analysis of variance (ANOVA) as described by Gomez and Gomez (1984) [7]. Treatment means were compared using the 'F' and 't' tests at the 5 per cent level of significance (P = 0.05). When the F-test was significant, the critical difference (CD) was computed; otherwise, results were denoted as 'NS' (non-significant).

Results and Discussion

Nutrient uptake

Data pertaining to effect of sunhemp seed rates and nitrogen management on nitrogen, phosphorus and potassium uptake in aerobic rice presented in table 1.

Among the sunhemp seed rate treatments, the use of sunhemp at 50 kg ha^{-1} recorded a significantly higher uptake of nitrogen (104.39 kg ha^{-1}), phosphorus (28.24 kg ha^{-1}) and potassium (97.16 kg ha^{-1}), compared to the treatments without sunhemp application, which registered lower nitrogen, phosphorus and potassium uptake (85.49, 23.13 and 79.24 kg ha^{-1}, for N, P and K, respectively). The treatment involving sunhemp at 75 kg ha^{-1} also recorded relatively higher values (101.53, 27.46 and 94.40 kg ha^{-1} for nitrogen, phosphorus and potassium, respectively) and was found to be significantly at par with 50 kg ha^{-1} in all the three nutrients.

In nitrogen management practices the application of 125 per cent recommended dose of nitrogen resulted in the significantly higher uptake of nitrogen (113.68 kg ha^{-1}), phosphorus (30.75 kg ha^{-1}) and potassium (105.63 kg ha^{-1}) and was found to be significantly higher than all other nitrogen levels. This was followed by 100 per cent RDN and 75 per cent RDN treatments. The lower nutrient uptake was observed in the treatment without nitrogen application (75.79, 20.50 and 70.44 kg ha^{-1} for N, P and K, respectively).

Table 1: Effect of sunhemp seed rates and nitrogen management on nutrient uptake in aerobic rice

Treatment	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
Sunhemp seed rate (S)									
S_0: 0 kg ha^{-1}	88.91	82.07	85.49	24.01	22.25	23.13	82.24	76.24	79.24
S_1: 50 kg ha^{-1}	107.95	100.83	104.39	29.15	27.34	28.24	99.86	94.46	97.16
S_2: 75 kg ha^{-1}	104.40	98.66	101.53	28.19	26.72	27.46	96.57	92.23	94.40
S.Em ±	1.69	1.52	1.64	0.46	0.41	0.44	1.56	1.25	1.35
CD (p=0.05)	4.96	4.44	4.81	1.34	1.20	1.30	4.59	3.67	3.95
Nitrogen management practices (N)									
N_0: 0% RDN	78.34	73.25	75.79	21.15	19.85	20.50	72.46	68.42	70.44
N_1: 75% RDN	97.06	90.73	93.89	26.21	24.59	25.40	89.78	84.73	87.25
N_2: 100% RDN	108.74	101.62	105.18	29.36	27.55	28.45	100.59	94.90	97.74
N_3: 125% RDN	117.55	109.81	113.68	31.74	29.76	30.75	108.73	102.52	105.63

S.Em ±	1.95	1.75	1.89	0.53	0.47	0.51	1.81	1.45	1.56
CD (p=0.05)	5.73	5.13	5.55	1.55	1.39	1.50	5.30	4.24	4.56
Interaction (S x N)									
S_0N_0	61.16	56.45	58.81	16.51	15.31	15.91	56.57	52.44	54.51
S_0N_1	83.78	77.32	80.55	22.62	20.97	21.79	77.49	71.84	74.66
S_0N_2	96.72	89.27	93.00	26.11	24.21	25.16	89.47	82.94	86.20
S_0N_3	114.00	105.22	109.61	30.78	28.53	29.66	105.45	97.75	101.60
S_1N_0	91.57	85.53	88.55	24.72	23.19	23.96	84.70	80.13	82.42
S_1N_1	103.80	96.95	100.38	28.03	26.29	27.16	96.02	90.83	93.43
S_1N_2	117.42	109.67	113.54	31.70	29.74	30.72	108.61	102.75	105.68
S_1N_3	119.01	111.16	115.09	32.13	30.14	31.14	110.09	104.14	107.12
S_2N_0	82.29	77.76	80.02	22.22	21.06	21.64	76.12	72.69	74.40
S_2N_1	103.60	97.90	100.75	27.97	26.52	27.24	95.83	91.52	93.67
S_2N_2	112.09	105.92	109.00	30.26	28.69	29.48	103.68	99.01	101.35
S_2N_3	119.63	113.05	116.34	32.30	30.62	31.46	110.66	105.68	108.17
S.Em ±	3.38	3.03	3.28	0.91	0.82	0.89	3.13	2.51	2.70
CD (p=0.05)	9.92	8.89	9.62	2.68	2.40	2.60	9.17	7.35	7.91

The interaction effect between sunhemp seed rate and nitrogen management was also found to be significant. The combination of sunhemp at 75 kg ha^{-1} along with 125 per cent RDN recorded the significantly higher uptake of nitrogen (116.34 kg ha^{-1}), phosphorus (31.46 kg ha^{-1}) and potassium (108.17 kg ha^{-1}). It was significantly at par with the combination of sunhemp at 50 kg ha^{-1} and 125 per cent RDN, (115.09, 31.14 and 107.12 kg ha^{-1} of N, P and K, respectively), 75 kg ha^{-1} with 100 per cent RDN, 50 kg ha^{-1} with 100 per cent RDN and no sunhemp with 125 per cent RDN. The lower uptake of all three nutrients was recorded in the interaction of no sunhemp and no nitrogen application, which showed 58.81, 15.91 and 54.51 kg ha^{-1} of nitrogen, phosphorus and potassium, respectively.

Increased nutrient uptake by rice in the rice + sunhemp system compared to sole rice cultivation can be attributed to the nitrogen-fixing ability of sunhemp, which enriches the soil with nitrogen, enhancing its availability to the rice crop. Moreover, the deep root system of sunhemp effectively scavenges nutrients from deeper soil layers, particularly phosphorus and potassium, making them more accessible to rice. This synergistic interaction improves overall nutrient availability, thereby promoting greater absorption by rice plants. Additionally, the decomposition of sunhemp residues releases organic acids that help in solubilizing fixed phosphorus, making it more readily available for plant uptake. These findings are consistent with those reported by Aruna and Mohammad (2005) [3] and Seema *et al.* (2015) [12]. Furthermore, increased levels of recommended dose of fertilizers significantly improved nutrient uptake by rice. This enhancement is likely due to the greater availability of nutrients, which supports vigorous plant growth and development, enabling rice plants to outcompete weeds and absorb more nutrients effectively.

Nutrient use efficiency

Observation effect of sunhemp seed rates and nitrogen management on phosphorus and potassium use efficiency in aerobic rice presented in table 2.

Rice + sunhemp at 50 kg ha^{-1} recorded significantly higher phosphorus and potassium use efficiency (89.07 and 89.07 kg kg^{-1}, respectively) and was on par with Rice + sunhemp at 75 kg ha^{-1} and sole rice cultivation without sunhemp recorded lower efficiency (70.07 and 70.07 kg kg^{-1} of phosphorus and potassium, respectively).

Among the different nitrogen management levels, 125 per cent RDN resulted in the significantly higher phosphorus and potassium use efficiency (102.61 and 102.61 kg kg^{-1}, respectively), followed by 100 per cent RDN (88.98 and 88.98 kg kg^{-1}), while the lower efficiencies were recorded under no nitrogen application (59.28 and 59.28 kg kg^{-1} of phosphorus and potassium, respectively).

Table 2: Effect of sunhemp seed rates and nitrogen management on phosphorus and potassium use efficiency in aerobic rice

Treatment	Phosphorus (kg kg^{-1})			Potassium (kg kg^{-1})		
	2023	2024	Pooled	2023	2024	Pooled
Sunhemp seed rate (S)						
S_0: 0 kg ha^{-1}	72.94	67.20	70.07	72.94	67.20	70.07
S_1: 50 kg ha^{-1}	92.25	85.89	89.07	92.25	85.89	89.07
S_2: 75 kg ha^{-1}	85.12	80.18	82.65	85.12	80.18	82.65
S.Em ±	2.44	2.29	2.36	2.44	2.29	2.36
CD (p=0.05)	7.16	6.71	6.94	7.16	6.71	6.94
Nitrogen management practices (N)						
N_0: 0% RDN	61.32	57.23	59.28	61.32	57.23	59.28
N_1: 75% RDN	74.06	68.99	71.52	74.06	68.99	71.52
N_2:100% RDN	92.12	85.84	88.98	92.12	85.84	88.98
N_3:125% RDN	106.24	98.97	102.61	106.24	98.97	102.61
S.Em ±	2.82	2.64	2.73	2.82	2.64	2.73
CD (p=0.05)	8.26	7.75	8.01	8.26	7.75	8.01
Interaction (S x N)						
S_0N_0	40.54	37.35	38.95	40.54	37.35	38.95
S_0N_1	64.40	59.34	61.87	64.40	59.34	61.87
S_0N_2	83.64	77.06	80.35	83.64	77.06	80.35
S_0N_3	103.18	95.06	99.12	103.18	95.06	99.12
S_1N_0	69.58	64.78	67.18	69.58	64.78	67.18
S_1N_1	91.08	84.80	87.94	91.08	84.80	87.94
S_1N_2	98.47	91.68	95.07	98.47	91.68	95.07
S_1N_3	109.87	102.30	106.08	109.87	102.30	106.08
S_2N_0	73.85	69.56	71.71	73.85	69.56	71.71
S_2N_1	66.69	62.82	64.76	66.69	62.82	64.76
S_2N_2	94.26	88.79	91.53	94.26	88.79	91.53
S_2N_3	105.68	99.55	102.62	105.68	99.55	102.62
S.Em ±	4.88	4.58	4.73	4.88	4.58	4.73
CD (p=0.05)	14.31	13.43	13.87	14.31	13.43	13.87

The interaction effect between sunhemp seed rate and nitrogen management practices revealed significant variations in phosphorus and potassium use efficiency. The combination of rice + sunhemp at 50 kg ha^{-1} with 125 per cent RDN recorded the significantly higher phosphorus and potassium use efficiency (106.08 and 106.08 kg kg^{-1}, respectively). It was significantly at par with the combination of sunhemp at 75 kg ha^{-1} with 125 per cent RDN, 50 kg ha^{-1} with 100 per cent RDN and no sunhemp with 125 per cent RDN. On the other hand, the lower

phosphorus and potassium use efficiency was observed in sole rice cultivation without nitrogen application, which recorded only 38.95 kg kg⁻¹ for both nutrients.

The enhanced nutrient use efficiency of rice in brown manured plots can be attributed to the additional biomass from sunhemp, which enriched the soil organic matter. This increase in organic content played a key role in improving the availability and absorption of essential nutrients by plants. Similar observations were made by Moe *et al.* (2017) [8]. Soil organic matter functions as a nutrient reservoir, reducing nutrient leaching and ensuring a steady supply to plants over time. Due to its high cation exchange capacity (CEC), it effectively holds and exchanges vital cations such as calcium, magnesium and potassium, making them readily available when required. The decomposed sunhemp mulch further contributed to improved soil structure by promoting aggregation, enhancing water infiltration and retaining moisture. These changes create favorable conditions for root development and nutrient uptake. Additionally, the improved organic matter supports robust root systems, which are more efficient at exploring ssoil and accessing nutrients. These findings are consistent with those of Seema *et al.* (2015) [12], Dey *et al.* (2016) [5] and Sarangi *et al.* (2016) [11].

Economics

Gross returns

The economic analysis revealed significant effects of sunhemp seed rate, nitrogen management and their interaction on gross returns, net returns and benefit-cost (B-C) ratio. In terms of gross returns, the higher pooled value was recorded with sunhemp 50 kg ha⁻¹ at ₹124202 ha^{-1}, followed by sunhemp 75 kg ha⁻¹ at ₹115518 ha^{-1}, while the lower was under no sunhemp application at ₹98067 ha^{-1}. Among nitrogen treatments, the higher gross returns were obtained with 125 per cent RDN at ₹142611 ha^{-1}and the lower with the control (no nitrogen application) at ₹83159 ha^{-1}. The interaction effect showed that the combination of sunhemp 50 kg ha⁻¹ + 125 per cent RDN yielded the higher pooled gross returns (₹147725 ha^{-1}), whereas the lower was seen in the no sunhemp + control treatment (₹ 56430 ha^{-1}).

Net returns

A similar trend was observed in net returns, where sunhemp 50 kg ha⁻¹ recorded the higher pooled net returns (₹66122 ha^{-1}), followed by sunhemp 75 kg ha⁻¹ (₹54939 ha^{-1}) and the lower in no sunhemp (₹44988 ha^{-1}). Nitrogen application at 125 per cent RDN led to the maximum net returns (₹84783 ha^{-1}), while the control resulted in the minimum (₹26787 ha^{-1}). The interaction of sunhemp 50 kg ha⁻¹ + 125 per cent RDN once again outperformed other combinations, with the higher net returns (₹89063 ha^{-1}) and no sunhemp + control had the least (₹4224 ha^{-1}).

Table 3: Effect of sunhemp seed rates and nitrogen management on gross returns, net returns and B-C ratio in aerobic rice

Treatment	Gross returns (₹ ha^{-1})			Net returns (₹ ha^{-1})			B-C ratio		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
Sunhemp seed rate (S)									
S_0: 0 kg ha^{-1}	102042	94092	98067	48962	41013	44988	1.92	1.77	1.84
S_1: 50 kg ha^{-1}	128592	119811	124202	70513	61732	66122	2.21	2.06	2.14
S_2: 75 kg ha^{-1}	118960	112077	115518	58381	51497	54939	1.96	1.85	1.90
Nitrogen management practices (N)									
N_0: 0% RDN	86010	80307	83159	29638	23935	26787	1.51	1.41	1.46
N_1: 75% RDN	103918	96863	100390	46672	39617	43144	1.82	1.69	1.75
N_2:100% RDN	128571	119873	124222	71033	62336	66685	2.23	2.08	2.16
N_3:125% RDN	147626	137596	142611	89798	79767	84783	2.56	2.38	2.47
Interaction (S x N)									
S_0N_0	58705	54154	56430	6500	1948	4224	1.12	1.04	1.08
S_0N_1	90454	83412	86933	37375	30333	33854	1.70	1.57	1.64
S_0N_2	116557	107470	112014	63187	54099	58643	2.18	2.01	2.10
S_0N_3	142450	131332	136891	88788	77670	83229	2.65	2.45	2.55
S_1N_0	96811	90193	93502	39605	32988	36297	1.69	1.58	1.63
S_1N_1	127077	118402	122740	68998	60323	64661	2.19	2.04	2.11
S_1N_2	137534	128146	132840	79164	69775	74469	2.36	2.20	2.28
S_1N_3	152947	142502	147725	94285	83840	89063	2.61	2.43	2.52
S_2N_0	102514	96575	99545	42809	36870	39839	1.72	1.62	1.67
S_2N_1	94223	88773	91498	33644	28194	30919	1.56	1.47	1.51
S_2N_2	131621	124004	127812	70750	63134	66942	2.16	2.04	2.10
S_2N_3	147482	138953	143218	86320	77791	82056	2.41	2.27	2.34

B-C ratio

In terms of the B-C ratio, sunhemp 50 kg ha⁻¹ registered the higher pooled ratio (2.14), with sunhemp 75 kg ha⁻¹ and no sunhemp following at 1.90 and 1.84, respectively. Increasing nitrogen rates improved profitability, with 125 per cent RDN achieving the higher B-C ratio (2.47) and control the lower (1.46). Notably, the B- B-C ratio was observed in the no sunhemp + 125 per cent RDN combination (2.55), followed by sunhemp 50 kg ha⁻¹ + 125 per cent RDN (2.52), while the lower was in the no sunhemp + control treatment (1.08), indicating that both sunhemp integration and enhanced nitrogen levels are crucial for maximizing economic returns in rice production.

The observed trends in gross returns, net returns and benefit-cost ratio were primarily attributed to the yield performance of the respective treatments. Higher gross returns in treatments such as sunhemp 50 kg ha⁻¹ and 125 per cent recommended dose of nitrogen resulted from increased grain and straw yields, which directly contributed to greater revenue generation. Treatments involving sunhemp incorporation improved soil fertility and nitrogen availability, while higher nitrogen application further supported vigorous crop growth, leading to enhanced productivity. Consequently, net returns were also higher in these treatments, as the additional income from increased yield substantially outweighed the added input costs of sunhemp seed

and fertilizers.

The interaction of sunhemp 50 kg ha^{-1} + 125 per cent RDN produced the higher net returns, confirming the synergistic effect of green manuring and optimal nitrogen management. Similarly, the B-C ratio followed the same trend, with higher ratios recorded in treatments that achieved better yield performance, indicating greater economic efficiency. Although higher input costs were involved, the returns from significantly higher yields more than compensated for them, resulting in improved profitability. Thus, the overall economic superiority of these treatments can be directly linked to their ability to produce higher yields, reinforcing the importance of integrated nutrient management in rice cultivation. These results were in line with the findings of Devi and Sumathi (2011) [4], Gaire *et al.* (2013) [6] and Amrutha *et al.* (2016) [1].

Conclusion

The study revealed that integrating sunhemp and higher nitrogen levels significantly improved nutrient uptake, nutrient use efficiency and profitability in aerobic rice. Sunhemp at 50 kg ha^{-1} recorded higher N, P_2O_5, and K_2O uptake compared to treatments without sunhemp. Application of 125 per cent RDN further enhanced nutrient absorption and crop performance. The combination of sunhemp at 50 kg ha^{-1} with 125 per cent RDN proved to be the most effective treatment. This combination achieved higher nutrient uptake and nutrient use efficiency. Improved soil fertility and increased organic matter from sunhemp incorporation enhanced nutrient availability. Higher nitrogen levels also supported vigorous plant growth and yield. The same combination recorded higher gross returns, net returns, and benefit-cost ratio. The economic gains were mainly due to increased grain and straw yields.

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