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Economics of Enhancing Kalanamak Rice (*Oryza sativa* L.) Production through Integrated Nutrient Management in Central Uttar Pradesh

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Abstract
A field experiment was conducted during the kharif seasons of 2022 and 2023 at Farmers' Field in Kishorpur village, Kanpur Dehat, under the supervision of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. The site lies in the alluvial belt of the Indo-Gangetic plains in central Uttar Pradesh, known for its fertile soil, ideal for agricultural research. There are 12 treatment combinations involved varying integration of macronutrients, i.e., N, P, K & S, micronutrients, i.e., Zn, organic manure, i.e., FYM and biofertilizers, i.e., BGA with three replications of randomized block design (RBD). The cultivation of Kalanamak variety, i.e., Kalanamak *Kiran* was carried out in accordance with the suggested agronomic practices. It can be concluded from the findings that the two-year results are consistent with the T_7 (100 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1} + BGA @ 10 kg ha^{-1}) showed the highest values of economics parameters, i.e., maximum cost of cultivation ₹49715 & ₹50414, gross returns of ₹145983 & ₹152878 and net return of ₹96268 & ₹102464 during the first year and second year, respectively, followed by treatment T_6. The study shows that BGA, Zn, and S improve grain yield and enhance the economic viability of Kalanamak rice cultivation. It emphasizes that integrated nutrient management, combining biofertilizer and balanced fertilization, optimizes economic returns.

Keywords: Kalanamak rice, zinc, BGA and net return

1. Introduction
Rice (*Oryza sativa* L.) is one of the important cereals crop mainly grown in *kharif* season and play very significant role in Indian food security (Singh *et al*., 2017) [13]. About 90% of rice grown in the world is produced and consumed in the Asia region, with China leading in production, followed by India. It is a good source of carbohydrate, fat, protein (mild concentration), and B complex vitamins such as niacin (Vitamin B_5), thiamine (Vitamin B_1), and riboflavin (Vitamin B_2), (Kowsalya *et al*., 2022) [9]. India is the second-largest rice producer and the largest exporter of rice in the world. India has the largest rice-growing area (46 million hectares) in the world but contributes less than a quarter of global production. Total production of rice during 2023-24 is estimated to be 135 million tonnes (USDA's Global rice production estimate 2023-2024). Uttar Pradesh is the second largest rice producing state with almost 5.87 million hectares of land (~13.5% of rice cultivated land of India) used for rice cultivation, producing about 19.9 million tonnes per year (11%-12% of rice grown in India).
Kalanamak is one of the finest quality aromatic rices of Nepal and India. In India, it is traditionally consumed in the north-eastern part of Uttar Pradesh (Chaudhary and Tran, 2001) [3] and is known as the scented black pearl of Uttar Pradesh. It was featured in the book 'Speciality

Rices of the World' by the Food and Agriculture Organization of the United Nations. Kalanamak rice is a healthier alternative to white rice due to its nutritious and medicinal value. It contains more Vitamin A, Protein, Iron, and Zinc as compared to white rice.Kalanamak rice is good for people with diabetes because it has a low Glycemic Index (49% to 52%), making it "sugar-free". Nutrient management is an important aspect in aromatic rice production for sustainable rice production, ensuring high economic returns and improved quality while also increasing soil nutrient use efficiency (NUE). The main objective of nutrient management is applying manures and fertilizers in proper amounts. The application of N, P, K, S and Zn increases rice yield (Chaudhary *et al*., 2017) [4].

Nitrogen (N) is an essential component of many plant compounds, such as chlorophyll, nucleotides, proteins, alkaloids, enzymes, hormones and vitamins. A vital component of rice production, nitrogen (N) is needed for the growth, development and productivity of all rice varieties, including the traditional aromatic Kalanamak variety. The productivity and financial return for farmers cultivating Kalanamak rice are directly impacted by proper nitrogen management. Enhancing the yield and economic feasibility of Kalanamak rice is mostly dependent on nitrogen. Higher productivity, better grain quality, and more financial gain for farmers are all possible outcomes of effective nitrogen management. To prevent adverse effects on the ecosystem and guarantee long-term sustainability in rice farming systems, it is imperative to maintain an appropriate nitrogen balance. Phosphorus (P) plays a crucial role in rice grain formation and significantly impacts productivity by promoting root development, enhancing energy transfer and supporting physiological processes, i.e., photosynthesis, respiration, energy storage and cell division enlargement. This leads to better grain filling, increased grain size and a higher number of grains pancle^{-1}, resulting in improved yields. Applying P fertilizer can improve the nutritional quality of rice (Hao *et al*., 2009) [7] and appropriately applying P at the heading stage will improve the eating quality of rice. Potassium (K) is a macronutrient for plants that is required for physiological processes such as the maintenance of membrane potential and turgor, activation of enzymes, regulation of osmotic pressure and stomata movement and tropisms (Golldack *et al*., 2003) [6]. Potassium prevents from lodging by providing strength to straw. A gradual increase in K rate increased grain yield, narrowed the grain:straw ratio, and steadily improved the harvest index. Potassium in rice producing soils is one of the limiting factors for increasing rice yield. The period of the highest potassium uptake is before the heading stage and little is absorbed after heading. After nitrogen, phosphorus, and potassium, sulphur (S) is the fourth major nutrient for plants and helps in amino acid and protein synthesis, enzymatic activation and metabolic activities in plants, which account for approximately 90% of organic S in the plant. The Farmyard Manure (FYM) is the indigenous source for the nutrient supply system, which is prepared easily and contains a substantial amount of plant nutrients for taking scented and quality rice. Organic manures have the capacity to fulfil nutrient demand of crops adequately and promote the activity of macro and micro flora in the soil. Combined application of N, P, K, S, Zn and biofertilizer increases the yield, uptake and quality of the crop (Sahu *et al*., 2017) [12]. Micronutrients play an important role in rice cultivation that does not mean that they are less important to plants than other nutrients; rather it indicates that they are required by plants in trace amounts, contributing to their growth and development. It is essential for several biochemical processes in the rice plant, such as cytochrome and nucleotide synthesis, auxin metabolism, chlorophyll production, enzyme activation and membrane integrity. The mineral zinc (Zn) also plays an important role in the reproductive process, such as the fertilization of the pollen grain and the formation of pollen grains. Zinc uptake is positively correlated with organic matter content and negatively correlated with phosphorus (P) concentration in the soil. Imbalanced nutrient application and excessive use of chemical fertilizers without the use of organic manures is deteriorating the soil quality productivity. Biofertilizers are living microorganisms that are bacterial, fungal, or algal in origin. Biofertilizers are low in cost, ecofriendly and renewable sources of plant nutrients to supplement or complement chemical fertilizers. Bio-fertilizers also play an important role in maintaining long term fertility and sustainability. Nitrogen fixing and P-solubilizing inoculants are important biofertilizers used in rice (Wijebandra *et al*., 2011) [14].

Blue Green Algae (BGA) or cyanobacteria which find a highly favourable abode in the waterlogged conditions of rice fields provide cheap nitrogen to plants besides increasing crop yield by making soil vital, fertile and productive. PUSA Algal Biofertilizer use in rice popularly known as 'Algalization' has been found to contribute up to 20-25 kg N per hectare per season and increase yield by 8-10% under favourable conditions. As a result of biofertilizers, atmospheric nitrogen is fixed in the root nodules and made available to plants. By applying nutrients at the appropriate dose, you can achieve a profitable as well as economically and environmentally optimal result.

2. Materials and Methods

A randomized block design (RBD) was adopted for the study, with 12 treatments replicated three times. The experiment consisted of various treatment combinations involving the application of macronutrients (N, P, K and S), organic manure (FYM), micronutrient (Zn) and biofertilizer (BGA). The details of the treatment and their combinations are depicted in the table 1.

Table 1: Details of treatments applied in Kalanamak rice

S. No.	Treatment combinations	Symbol
1.	Control	T_1
2.	125 per cent RDF	T_2
3.	100 per cent RDF	T_3
4.	100 per cent RDF + 25 per cent N FYM	T_4
5.	100 per cent RDF + 25 percent N FYM + S @ 40 kg ha^{-1}	T_5
6.	100 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1}	T_6
7.	100 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1} + BGA @ 10 kg ha^{-1}	T_7
8.	75 per cent RDF	T_8
9.	75 per cent RDF + 25 per cent N FYM	T_9
10.	75 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1}	T_{10}
11.	75 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1}	T_{11}
12.	75 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1} + BGA @ 10 kg ha^{-1}	T_{12}

RDF - Recommended dose of fertilizer

2.1 Economic Characters

Production economics in agriculture typically includes key financial indicators such as the cost of cultivation, gross return and net return. These components assist in evaluating the overall economic performance and profitability of farming practices. Grain and straw yield are based on an average in respective years, i.e., 2022 and 2023; different treatments were analyzed economically.

2.1.1 Cost of cultivation (₹ ha^{-1}): Calculation of cost of cultivation based on input rates at the farm. The costs related to the treatments were calculated independently. To obtain the total cost of cultivation, all expenses incurred in cultivation were considered, and treating costs (including interest on working capital) were added.

2.1.2 Gross return (₹ ha^{-1}): Market rates were used to calculate the income from grain and straw production. Gross return per hectare was calculated by converting Kalanamak rice crop yields to current produce prices.

Gross return (₹ ha^{-1}) = Total income from grain and Straw yield

2.1.3 Net return (₹ ha^{-1}): To calculate profit, subtract cultivation cost from gross income (₹ ha^{-1}). Following is the formula used to calculate the net return:

Net return (₹ ha^{-1}) = Gross return (₹ ha^{-1}) - Cost of cultivation (₹ ha^{-1})

Table 2: Treatment wise grain and straw yield (q ha^{-1})

	Treatment Combinations	Grain yield (q ha^{-1})			Straw yield (q ha^{-1})		
		2022	2023	Pooled	2022	2023	Pooled
T_1	Control	25.45	26.23	25.84	47.59	48.53	48.06
T_2	125 per cent RDF	34.10	35.15	34.63	60.18	61.51	60.85
T_3	100 per cent RDF	32.56	34.01	33.29	58.28	60.20	59.24
T_4	100 per cent RDF + 25 per cent N FYM	35.45	36.23	35.84	62.04	62.68	62.36
T_5	100 per cent RDF + 25 per cent N FYM + S @ 40 Kg ha^{-1}	37.56	38.39	37.98	64.23	64.88	64.56
T_6	100 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 Kg ha^{-1}	42.34	43.21	42.78	69.44	70.00	69.72
T_7	100 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1} + BGA @ 10 kg ha^{-1}	44.78	45.42	45.10	71.65	71.76	71.71
T_8	75 per cent RDF	27.34	28.33	27.84	50.58	51.84	51.21
T_9	75 per cent RDF + 25 per cent N FYM	29.76	30.90	30.33	54.46	55.93	55.20
T_{10}	75 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1}	31.34	32.73	32.04	56.73	58.59	57.66
T_{11}	75 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1}	36.89	37.73	37.31	63.82	64.52	64.17
T_{12}	75 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1} + BGA @ 10 kg ha^{-1}	39.45	40.30	39.88	66.28	66.90	66.59
	SEm ±	0.783	0.743	0.8	1.253	1.362	1.336
	C.D. at 5%	2.312	2.192	2.361	3.698	4.02	3.944

Table 3: Impact of treatments on Cost of Cultivation (₹), Gross Return (₹) and Net Return (₹) of Kalanamak Rice

	Treatment Combinations	Cost of cultivation (₹)		Gross return (₹)		Net return (₹)	
		2022	2023	2022	2023	2022	2023
T_1	Control	41393	42092	83654	89031	42261	46939
T_2	125 percent RDF	49781	50480	111728	118939	61947	68458
T_3	100 percent RDF	48093	48792	106764	115153	58671	66361
T_4	100 percent RDF + 25 percent N FYM	48130	48829	116099	122517	67669	73688
T_5	100 percent RDF + 25 percent N FYM + S @ 40 Kg ha^{-1}	48680	49379	122859	129660	74179	80281
T_6	100 percent RDF + 25 percent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 Kg ha^{-1}	49215	49914	138198	145622	88983	95708
T_7	100 percent RDF + 25 percent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1} + BGA @ 10 kg ha^{-1}	49715	50414	145983	152878	96268	102464
T_8	75 percent RDF	44010	45116	89812	96099	45802	50983
T_9	75 percent RDF + 25 percent N FYM	46874	47573	97702	104752	50828	57179
T_{10}	75 percent RDF + 25 percent N FYM + S @ 40 kg ha^{-1}	47842	48123	102827	110887	54985	62764
T_{11}	75 percent RDF + 25 percent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1}	47959	48658	120741	127510	72782	78852
T_{12}	75 percent RDF + 25 percent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1} + BGA @ 10 kg ha^{-1}	48459	49158	128923	135984	80464	86826

3. Results and Discussion

The data pertaining to economics of Kalanamak rice was studied in terms of cost of cultivation, gross return and net return which have been shown the economics data in table 3. The calculations of cost of cultivation (₹ ha^{-1}), gross return (₹ ha^{-1}) and net return (₹ ha^{-1}) have been done in both years (2022 and 2023). It is visualized in data regarding economic analysis, i.e., cost of cultivation, which showed that maximum cost of cultivation ₹ 49715 and ₹ 50414 were recorded with the treatment T_7 (100 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1} + BGA @ 10 kg ha^{-1}) followed by ₹ 49215 and ₹ 49914 in the treatment T_6 (100 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1}) and minimum cost of cultivation i.e. ₹ 41393 and ₹ 42092 were recorded in treatment T_1 (control) during first and second year respectively. Data in regard to economic analysis, i.e., gross return, which showed that maximum gross return ₹ 145983 and ₹ 152878 were recorded with the treatment T_7 (100 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1} + BGA @ 10 kg ha^{-1}) followed by ₹ 138198 and ₹ 145622 in the treatment T_6 (100 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1}) and minimum gross return ₹ 83654 and ₹ 89031 were recorded in treatment T_1 (control) during first and second year respectively. It is apparent from data regarding economic analysis, i.e., net return which showed that maximum net return ₹ 96268 and ₹ 102464 were recorded with the treatment T_7 (100 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1} + BGA @ 10 kg ha^{-1}) followed by ₹ 88983 and ₹ 95708 in the treatment T_6 (100 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1}) and minimum net return ₹ 42261 and ₹ 46939 were recorded in treatment T_1 (control) during first and second year respectively. The favourable influence of applied Zn on yield might be due to its catalytic stimulatory effect on most of the physiological and metabolic process of plant (Mandal *et al*. 2009). The treatment combination of 100 per cent RDF, 25 per cent N from FYM, 40 kg ha^{-1} S, 5 kg ha^{-1} ZnO, and 10 kg ha^{-1} BGA proved to be economically superior to other treatments. High net returns (₹ ha^{-1}) have been observed in treatment T_7. One reason for the high net returns is the higher selling price of Kalanamak rice compared to conventional or HYV rice. Normal selling price of Kalanamak rice ranges between ₹ 3000 to ₹ 4000 per quintal. This might also be due to less cost incurred and obtained higher gross return. These outcomes are in close conformity with the findings of (Yadav *et al*., 2019) [15], **(**Chaudhary *et al*., 2012) [1], (Panidan *et al*., 2001) [11], (Ghatak *et al*., 2005) [5] and (Khanda and dixit, 1996) [8].

4. Conclusion

In the light of results summarized above in conclusion, the application of treatment T_7 had maximum cost of cultivation but produced more gross return and net returns. Hence, applying key elements in the correct proportion and quantity is crucial for increasing profit and achieving higher net returns, as demonstrated by treatment T_7 (100 per cent RDF + 25 per cent N FYM + S @ 40 kg ha^{-1} + ZnO @ 5 kg ha^{-1} + BGA @ 10 kg ha^{-1}) which proved to be the most cost-effective. So, we can recommend treatment T_7 to Kalanamak rice growing farmers.

5. Competing Interests

All authors have stated that there have no competing interests.

6. Acknowledgement

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