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POTASSIUM MANAGEMENT STRATEGIES FOR ENHANCING PRODUCTIVITY AND NUTRIENT USE EFFICIENCY OF RICE UNDER HIGH-RAINFALL CONDITIONS

N. Bommayasamy[1*], Y. Ramakrishna[2] and V. Kannan[3]

[1]ICAR- Central Coastal Agricultural Research Institute, Old Goa - 403 402, Goa, India.
[2]ICAR-Central Island Agricultural Research Institute, Port Blair - 744 105, Andaman & Nicobar Islands, India.
[3]Tamil Nadu Dr. J. Jayalalitha Fisheries University, Sikkal, Nagapattinam - 611 108, Tamil Nadu, India.
*Corresponding author E-mail : samygs81@yahoo.co.in
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ABSTRACT

Potassium (K) is essential for enhancing rice productivity, especially under high rainfall circumstances that result in substantial nutrient losses. An on-farm experiment was conducted in the Andaman and Nicobar Islands to assess the impact of varying potassium levels on the growth, production, nutrient use efficiency, and economic viability of rice. The treatments comprised T_1 (0% K), T_2 (50% K), and T_3 (100% K), in addition to the recommended dose of nitrogen and phosphorus. The results indicated that potassium management markedly improved plant growth, root development and yield characteristics. T_3 exhibited the maximum plant height (138.4 cm), root length (25.6 cm), productive tillers (16.4 hill^{-1}), and total filled grains (120 panicles^{-1}). Grain yield increased by 13.2% under 100% of recommended K relative to the control, while straw output enhanced by 6.7%. The nutrient utilisation efficiency was maximised under T_3, exhibiting an agronomic efficiency of 17.0%. The economic investigation revealed that 100% recommended K achieved the highest net return (Rs. 25,710 ha^{-1}) and benefit-cost ratio (2.32), reflecting a 20.8% increase compared to the control group. The research indicates that optimal potassium fertilisation markedly enhances productivity, nutrient efficiency, and profitability of rice in high rainfall habitats.

Key words : Potassium fertilization, Nutrient use efficiency, High rainfall, Yield, Economics.

Introduction

Rice (*Oryza sativa* L.) is an important food source that helps keep the world's food supply stable, especially in Asia and other developing countries. The Andaman and Nicobar Islands cultivate paddy as the principal cereal crop over approximately 8,549 ha of low-lying valley lands. The Islands currently produce about 26,249 tonnes of rice annually, with an average productivity of only 2.2 t ha^{-1}. Consequently, nearly 27,188 tonnes of rice are imported from mainland India to meet local demand (Bommayasamy *et al*., 2019; Subramani *et al*., 2014). The Andaman and Nicobar Islands receive high annual rainfall (around 3000–3200 mm), mainly during the southwest monsoon period. This has a significant impact on nutrient dynamics in rice ecosystems. Heavy rainfall leads to substantial nutrient losses through leaching, runoff, and percolation, particularly of mobile nutrients such as nitrogen and potassium. Consequently, nutrient use efficiency is often low under these conditions, necessitating the adoption of site-specific and split nutrient management strategies. Efficient nutrient management, especially the balanced application of nitrogen, phosphorus, and potassium, is therefore essential to compensate for these losses and sustain crop productivity in high rainfall regions (Bommayasamy *et al*., 2024). Potassium (K) is an important macronutrient that is very important for plant physiological and biochemical functions, such as photosynthesis, osmotic control, enzyme activation, and assimilate translocation. Having enough potassium helps roots grow, makes plants use water more efficiently, and makes them more resistant to stress from the environment. Recent research indicates that proper potassium fertilization markedly enhances dry matter buildup, nitrogen absorption, and overall crop performance in rice systems (Chen *et al*., 2024). Potassium fertilization is important, yet in many rice-growing areas, it is often not done or not done enough compared to nitrogen and phosphate. This mismatch makes it less efficient to consume nutrients (NUE) and lowers the potential yield. Potassium is also very likely to leak out when it rains a lot since it is ionic and doesn't stick well to soil particles, especially in soils with a lot of coarse texture. Lingappa *et al*. (2024) found that continuous cultivation without sufficient potassium replenishment leads to soil K depletion and lower production over period of time. Balanced fertilization with nitrogen (N), phosphorus (P) and potassium (K) has been demonstrated to greatly improve rice's ability to take up nutrients, its grain yield, and how well it uses nutrients. Integrated N and K management not only makes better use of fertilizers, but it also reduced on nutrient losses and makes cropping systems more sustainable (Liu *et al*., 2025). Optimized potassium application can significantly enhance agronomic efficiency and yield components, underscoring its vital importance in rice production systems (Cao *et al*., 2025). Recent experimental research indicates that balanced NPK fertilization enhances nutrient accumulation and grain yield, whereas excessive nitrogen in the absence of sufficient potassium may diminish productivity and nutrient efficiency. Consequently, effective nutrient management strategies are crucial for attaining sustainable intensification of rice production (Swai *et al*., 2026). Numerous studies have highlighted the advantages of potassium fertilization; nevertheless, there is a paucity of research examining its function in high-rainfall ecosystems, especially in island and coastal areas characterized by significant nutrient variability. Consequently, formulating location-specific potassium management techniques is crucial for enhancing rice yield and maintaining soil fertility under these circumstances. This study was conducted to assess the impact of potassium fertilizer on the growth, production and nutrient use efficiency of rice in high-rainfall areas.

Materials and Methods

During the *Kharif* season (June to October, 2013-14), on-farm trials were conducted in a farmer's field at Chidiyatapu, in the Andaman and Nicobar Islands agro-climatic zone. The experimental site is located at 11°51′ N latitude and 92°69′ E longitude, 10 m above mean sea level (MSL) and receives an average of 3080 mm of rain per year in a humid tropical climate. The soil in the experimental field was clay loam in texture with pH 7.1, and had an electrical conductivity of 0.18 dS m^{-1}. The soil had 0.33% organic carbon, 168.5 kg ha^{-1} nitrogen, 10.2 kg ha^{-1} phosphorus and 116.3 kg ha^{-1} potassium, indicating a low to medium fertility status. The experiment was set up in a randomized complete block design (RCBD) with seven replications. The treatments T_1 (100% N:100% P:0% K), T_2 (100% N:100% P:50% K), and T_3 (100% N :100% P: 100% K) were tested, along with recommended nitrogen and phosphorus. Pre-germinated seeds of MTU 1010 were seeded in wet nursery beds during the second week of June and transplanting was done in the second week of July, with two-three seedlings per hill at a spacing of 20 cm×15 cm. Island ecosystem's receiving heavy rainfall, fertilizers were given in split dosages to reduce nutrient losses. The recommended dose of 90:60:40 kg N:P_2O_5: K_2O ha^{-1} was applied using urea, rock phosphate, and muriate of potash. Nitrogen was applied in three equal parts *viz*., ten days after transplanting (DAT), at the maximum tillering stage, and at the panicle initiation stage. Full doses of phosphorus were given as a basal dose. The potassium was given in two equal doses, with half of it as a basal dose and the other half during panicle initiation stage. A tractor-drawn cage wheel was used to puddle the field, which is a standard procedure in lowland rice farming. This helped keep the water layer thin and cut down on percolation losses. There was no need for irrigation because there was enough rain. Instead, field bunds were made stronger to hold rainwater and good drainage systems were kept up to get rid of extra water during heavy rain. Pest and disease management procedures were used only when they were needed.

Yoshida's (1972) standard procedures for recording growth and yield parameters were used. The grain yield of each plot was calculated by sun-drying, and weighing the grain at a moisture level of 14%. However, the straw was sun dried for three days and weighed separately. The yields of both grain and straw were given in kg ha^{-1}. Economic analysis by calculating the expenses of cultivation, gross returns, net returns, and the benefit-cost ratio based on prevailing market prices for inputs, output, and labour wages. The experimental data were subjected to statistical analysis using analysis of variance (ANOVA) appropriate for randomised complete block design (RCBD), following the methodologies established by Gomez and Gomez (1984), with treatment differences assessed at the 5% probability level (P = 0.05).

Results and Discussion

The height of rice plants was considerably affected by varying doses of potassium fertilization (Table 1). The tallest plants, measuring 138.4 cm, were observed under T_3 (100% K), which was statistically superior to 50% K (136.2 cm) and 0% K (120.5 cm). The increase in plant

Table 1 : Influence of potassium fertilizer on growth, yield attributes of rice in high rainfall areas.

Treatments	**Plant height (cm)**	**Root characteristics**		**Yield attributes**		
		Root length (cm)	**Root dry weight (g/hill)**	**Productive tillers/ hill**	**Filled grains /Panicle (nos.)**	**Test weight (g)**
T_1 – (100% N:100% P:0% K)	120.5	22.9	17.6	11.2	100	19.7
T_2 – (100% N:100% P:50% K)	136.2	24.5	20.4	13.7	107	21.0
T_3 – (100% N:100% P:100% K)	138.4	25.6	21.9	16.4	120	22.3
SEm	2.62	0.8	0.7	0.7	2.5	1.0
CD (P=0.05)	5.71	1.8	1.6	1.5	5.4	2.2

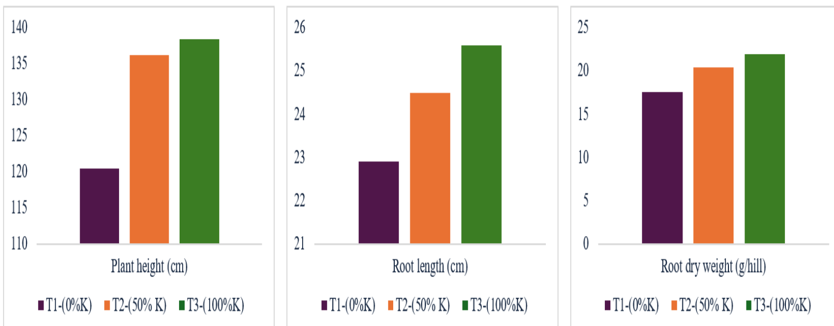

Fig. 1 : Influence of potassium fertilizer on growth attributes of rice in high rainfall areas.

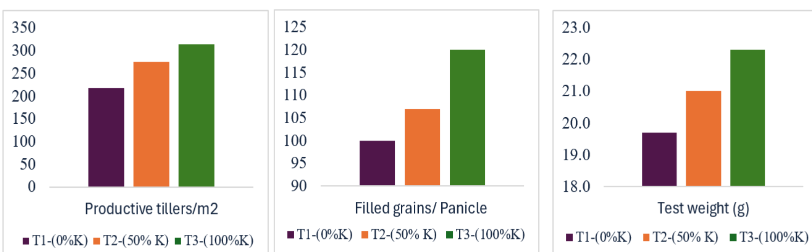

Fig. 2 : Influence of potassium fertilizer on yield attributes of rice in high rainfall areas.

height caused by potassium treatment can be linked to its important role in physiological and biochemical activities such as enzyme activation, protein synthesis, photosynthesis and stomatal opening regulation. Potassium promotes cell elongation and division, which boosts plant growth and biomass accumulation (Marschner, 1995, 1995). It also improves nutrient uptake, particularly nitrogen, which contributes to greater vegetative growth. Potassium availability is frequently reduced during high rainfall conditions due to leaching losses. According to Amanullah *et al.* (2016), a proper application of potassium guarantees that sufficient sources of nutrients are available during the whole growth phase of the crop, which ultimately results in an increase in plant height. Rengel (2015) emphasized that potassium enhances root development and nutrient acquisition, thereby indirectly contributing to increased plant height and stem growth.

Root characteristics : The root characteristics of rice were markedly affected by potassium fertilization (Table 1). The maximum root length (25.6 cm) and root dry weight (21.9 g) were observed in T_3 (100% K), followed by T_2, whereas the minimum values were found in T_1 (control). The enhancement of root growth with potassium supplementation is due to its function in controlling osmotic stability, stimulating enzymes, and encouraging cell division, all of which combined foster root elongation and biomass accumulation. Potassium enhances root architecture and boosts the efficiency of nutrient and water absorption, which is especially vital in high rainfall conditions where nutrient leaching occurs (Bommayasamy *et al.*, 2020; Chen *et al.*, 2024, 2024). Also, potassium fertilization promotes root development and nutrient absorption efficiency, facilitating improved acquisition of vital elements like nitrogen and phosphorus, thereby boosting overall plant growth (Carmeis Filho *et al.* (2017); Li *et al.* (2025) have also found that balanced potassium management enhances root biomass and function, which is closely associated with improved dry matter accumulation and nutrient use efficiency. The notable enhancement in root length and root dry weight at elevated potassium levels underscores the essential function of potassium in fostering a resilient root system and maintaining rice yield in heavy rainfall conditions.

Yield attributes of rice : Potassium fertilization enhanced the number of productive tillers substantially (Table 1). T_3 (100% K) produced the most productive tillers (313 m^{-2}), followed by T_2 (275 m^{-2}), while the control (217 m^{-2}) had the fewest. This indicates a 32.9% increase under T_2 and a 51.2% increase under T_3 in comparison to the control. The significant increase in productive tillers caused by potassium supplement can be related to its role in boosting nutrient usage efficiency, photosynthetic activity, and carbohydrate metabolism, all of which are necessary for tiller initiation and survival. Potassium improves assimilate synthesis and partitioning, resulting in a more consistent source of energy for secondary tillers. It also modulates enzymatic activity and cellular turgor, which stimulates vegetative growth and tillering capacity(Damodaran *et al.*, 2015; Zörb *et al.*, 2014). Sustained nutrient availability and improved root activity are guaranteed by an adequate potassium supply in high-rainfall environments, which also results in enhanced tiller formation. Balanced potassium fertilization improves nutrient uptake and physiological efficiency in rice systems, increasing effective tiller number (Chen *et al.*, 2024). Similarly, integrated nutrient management using potassium has been found to increase tiller density and crop productivity under a variety of agro-climatic situations (Li *et al.*, 2025).

Fig. 3 : Influence of potassium fertilizer on grain and straw yield of rice in high rainfall areas.

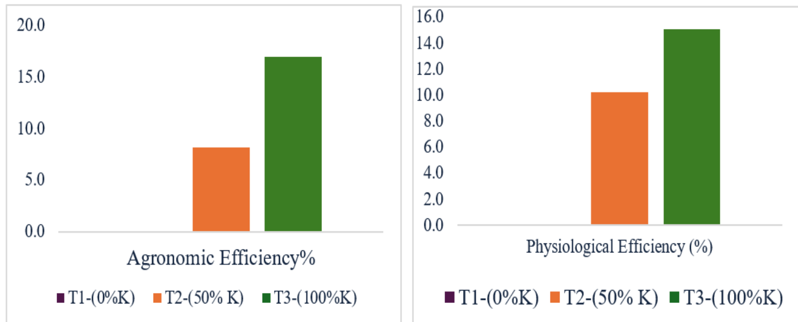

Fig 4. Influence of potassium fertilizer on NUE of rice in high rainfall areas

Fig. 4 : Influence of potassium fertilizer on NUE of rice in high rainfall areas.

Potassium fertilization had a substantial effect on the number of grains per panicle (Table 1). The highest number of filled grains (120 panicle^{-1}) was recorded under T_3 (100% K), followed by T_2 (107 panicle^{-1}) and the lowest was observed in the control (T_1: 100 panicles^{-1}). This indicates a 7.0% increase under T_2 and a 20.0% increase under T_3 in comparison to the control. Potassium application may enhance the number of filled grains per panicle because it improves photosynthesis, assimilate translocation, and enzyme activity, all of which are required for grain filling. According to Cakmak (2005), Pettigrew (2008), potassium enhances source-sink relationships by enabling the efficient transfer of carbohydrates from leaves to developing grains, which in turn decreases spikelet sterility and increases grain filling percentage. Potassium is also essential during the reproductive phase, as it enhances the viability of pollen, the development of panicles, and the setting of grains. Adequate potassium feeding improves nutrient availability throughout the grain filling stage, especially under high rainfall conditions when nutrient losses are widespread. Potassium fertilization improves physiological efficiency and nutrient uptake in rice, increasing grain filling and production (Dobermann and Fairhurst, 2000).

Grain and straw yield : Potassium fertilisation considerably influenced rice grain and straw yields (Table 2). The maximum grain yield (4523 kg ha^{-1}) was obtained under T_3 (100% K), followed by T_2 (4252 kg ha^{-1}) and the lowest in the control (T_1 : 39.97 kg ha^{-1}). T_2 and T_3 showed a 6.4% and 13.2% more grain yield over the control, respectively. Straw yield increased from 5790 kg ha^{-1} (control) to 6010 kg ha^{-1} (T_2) and 6180 kg ha^{-1} (T_3), with increases of 3.8% and 6.7%, respectively. The rise in yield could be due to a combination of better growth and yield factors throughout crop growing period. The increase in grain production following potassium application could be attributable to enhanced growth characteristics and yield qualities such as tiller number, grain filling, and test weight. Potassium improves photosynthesis efficiency, enzyme activity, and assimilate translocation, all of which contribute to increased grain yield. It also enhances source-sink interactions and decreases spikelet sterility, resulting in higher grain output. Potassium promotes photosynthesis, enzyme activity, and nutrient uptake, resulting in higher biomass and grain yield. Potassium application increases rice grain yield by 5.57 to 32.7% above the control due to enhanced photosynthesis and carbohydrate buildup, depending on soil and environmental conditions (Damodaran *et al.*, 2012; Gao *et al.*, 2025; Liu *et al.*, 2025). There is a strong correlation between enhanced potassium intake and increased rice output. This is due to the fact that increasing availability of potassium directly enhances crop productivity. In high rainfall conditions, adequate potassium delivery is critical for compensating for nutrient losses from leaching and maintaining constant yield levels.

Table 2 : Influence of potassium fertilizer on yield, nutrient use efficiency and economics of rice in high rainfall areas.

Treatments	Yield (kg ha^{-1})		Nutrient use efficiency		Economics	
	Grain yield	Straw yield	Agronomic Efficiency%	Physiological Efficiency (%)	Net return (Rs/ ha)	B Cratio
T_1 – (100% N:100% P:0% K)	3997	5790	-	-	21290	2.14
T_2 – (100% N:100% P:50% K)	4252	6010	8.2	10.21	23420	2.23
T_3 – (100% N:100% P:100% K)	4523	6180	17.0	15.04	25710	2.32
SEm	158	296	-	-	-	-
CD (P=0.05)	344	645	-	-	-	-

Fig. 5 : Influence of potassium fertilizer on economics of rice in high rainfall areas.

Nutrient use efficiencies : Potassium fertilisation had a significant effect on nutrient usage efficiency (NUE), as measured by agronomic efficiency (AE) and Physiological efficiency (PE) (Table 2). The maximum AE (17.0%) and PE (15.04%) were obtained under T_3 (100% K), while lesser values were reported under T_2. The control showed no efficacy due to the lack of potassium treatment. This clearly shows that potassium application improves the efficacy of provided fertilisers under high rainfall conditions. It is possible that improved nutrient absorption, transport and utilisation within the plant system are responsible for the increase in NUE that occurs in conjunction with an increase in potassium levels. A synergistic relationship exists between potassium and nitrogen, since potassium helps to improve nitrogen absorption and assimilation, which in turn leads to an increase in overall nutrient recovery and a decrease in losses. Imbalanced nutrient application, particularly with inadequate potassium availability, has been shown to impair nutrient uptake efficiency and destabilise yield potential (Li *et al.*, 2025). Furthermore, extensive evaluations have revealed a robust positive correlation between nutrient use efficiency and yield, suggesting that enhanced NUE directly facilitates increased productivity and sustainability in rice systems. Efficient potassium management improves nutrient recovery, decreases nutrient losses and facilitates long-term rice production intensification (Awio *et al.*, 2026; Velmurugan *et al.*, 2021).

Economic analysis : Economic investigations indicate that optimal potassium application increases profitability by maximising yield response and ensuring cost efficiency of inputs. Potassium fertilisation had a substantial effect on net return and the benefit-cost (B:C) ratio (Table 2). T_3 (RDF 100% K) had the highest net return (Rs. 25,710 ha^{-1}) and B:C ratio (2.32). T_2 (Rs. 23,420 ha^{-1}, B:C = 2.23) and T_1 (Rs. 21,290 ha^{-1}, B:C = 2.14). The net return increased by 10.0% (T_2) and 20.8% (T_3) over the control, whereas the B:C ratio improved by 4.2% (T_2) and 8.4% (T_3). The increased grain and straw harvests, which outweigh the additional cost of potassium fertiliser, may be the reason for the increase in net return and B:C ratio with potassium application. Potassium improves nutrient use efficiency, photosynthesis, and assimilate translocation, which leads to enhanced productivity and profitability. These conclusions are corroborated by recent research that suggests that the economic benefits of rice cultivation are substantially enhanced by potassium fertilisation. For instance, the use of optimised potassium led to an increase in net returns and the B:C ratio as a result of improved nutrient efficiency and a higher yield (Banerjee *et al.*, 2018).

Conclusion

The results clearly indicates that potassium boosts rice productivity in high-rainfall conditions. 100% recommended potassium improved growth, yield attributes, grain yield, nutrient use efficiency, and economic returns. Balanced fertilisation compensates for leaching losses and maximises nutrient use and productivity. Thus, potassium, nitrogen and phosphorus are needed to boost rice yield and profitability in high-rainfall ecosystems.

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