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Optimizing Rice Productivity in Coastal Saline Ecosystems of West Bengal through Foliar Application of Liquid Fertilizers

RAJIB KUNDU[1], TAKBIR ALI[1]*, KOUSHIK BRAHMACHARI[1], CHANDAN DE[1], SHUBHAMAY DEY[1], RATNESWAR PODDAR[1], GOLAM MOINUDDIN[1] and ARUP SEN[2]

[1]Department of Agronomy, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia-741 252, West Bengal, India
[2]Department of Agricultural Chemistry & Soil Science, Faculty of Agriculture, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia-741 252, West Bengal, India

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The imbalanced and excessive application of chemical fertilizers in saline coastal soils has led to declining factor productivity, yield stagnation and environmental degradation. This under scores the necessity of implementing sustainable nutrient management approaches to ensure productive and environmentally sound rice cultivation. Hence, a two-year field investigation was conducted during the 2023-2024 *Kharif* seasons at Rangabelia, Gosaba in South 24 Parganas district of West Bengal to assess the agronomic and economic feasibility of integrating liquid fertilizers with conventional soil fertilization in paddy production. The study was conducted using a randomized complete block design involving six treatments: 100% recommended dose of fertilizer (RDF_{NPK}) through conventional fertilizers, graded levels of RDF_{NPK} (75% and 50%) in combination with fortified nitrogen and phosphorus (NP, 7:21) and potassium thiosulphate ($K_2S_2O_3$) at two application rates, along with an unfertilized control, replicated four times. Among the treatments, foliar spray of fortified NP at 6.5 L ha^{-1} and $K_2S_2O_3$ at 5.0 L ha^{-1} applied at 30, 45 and 65 days after transplanting (DAT) in combination with 75% soil-applied RDF_{NPK} showed the most promising results through improving growth, yield and nutrient uptake as compared to the treatment receiving 100% RDF_{NPK} through soil applied chemical fertilizers. This treatment achieved the maximum grain yield of 4.84 t ha^{-1}, representing a 137% increase over the unfertilized control along with the maximum straw yield of 6.22 t ha^{-1}, harvest index of 43.76%, improved head rice recovery (%) and greater economic return (B:C=1.62). The findings highlight that partial substitution of soil-applied fertilizers (25% reduction in RDF_{NPK}) through liquid fertilizers can sustain productivity while enhancing economic returns and reducing environmental foot prints. In a nutshell, it can be opined that the combined application of liquid fertilizers with reduced RDF_{NPK} represents a viable and eco-efficient crop nutrition approach for sustainable rice cultivation in vulnerable coastal agro-ecosystems.

(***Key words:*** *Coastal agro-ecosystems, Kharif rice, Liquid fertilizers, Nutrient management, Potassium)*

Rapid modernization, industrialization vis-a-vis infrastructural development throughout the country resulted in sharp decline in net sown area under rice cultivation (Bhattacharyya *et al.,* 2015). Naturally, the state of West Bengal also, being the second largest rice producer in India, is not out of such scenario (Kumar *et al.,* 2022). A bridging gap between declining production and increasing demand could lead to increased dependency on imports. The predominance of medium and low-lying lands in eastern India coupled with high precipitation during *Kharif* season leave farmers with little choice but to cultivate rice which thrives in water-logged condition (Dar *et al.,* 2017). West Bengal is a region renowned for its rich rice biodiversity and plays a pivotal role in safeguarding the national grain reserve. The issue becomes more critical with in the coastal agro-ecosystems, like the Indian Sundarbans, where rice cultivation serves not only as a primary economic activity but also as the principal source of livelihood for millions of small holders and marginal farming households (Ray *et al.,* 2023). *Kharif* rice occupies approximately 3.29 lakh ha in South 24 Parganas district and produces about 8.23 lakh tonnes of rice with an average yield of 2.50 t ha^{-1}, making it one of the leading rice-growing districts of Coastal Saline Zone (CSZ) (Directorate of Agriculture, GoWB, 2023). Within the CSZ of West Bengal, rice-based monocropping systems dominate the production landscape, accounting for nearly 17% of the

*Corresponding author: E-mail: takbirali123@gmail.com

total acreage of the state under rice cultivation (Adak *et al.,* 2020). Amongst around 10 lakh ha rice growing area under coastal agro-ecosystem, the majority of the farmers are in the practice of following their traditional means to cultivate long duration rice cultivars keeping the updated rice producing agro-techniques almost untouched during wet season (Banerjee *et al.,* 2018). However, the sustainability of this system is threatened by uncertain yields and economic return jeopardizing farm livelihoods periodically under the influence of increasing environmental stresses (Rahaman *et al.,* 2023). Among the prime abiotic stresses, prolonged water stagnation, complete submergence and varying salinity levels of soil and water make the coastal ecosystem almost incompetent for enhancing quantity and quality of its staple food in their own fields (Sarangi *et al.,* 2020). Considering the immense potential of rice production in this region, adoption of advanced and futuristic nutrient management strategies make it possible to narrow down the yield gap. In the fragile coastal environments, out of varied strategies liquid fertilizers may provide distinct advantages over conventional fertilizers by offering rapid nutrient absorption, minimizing nutrient runoff and water pollution, checking the decline in soil health, enhancing crop productivity and increasing nutrient use efficiency; thereby, contributing to resilience largely against environmental stresses. In the vulnerable coastal agro-ecosystems usually prone to nutrient loss and soil degradation, the liquid forms of fertilizer would surely be a sustainable alternative in plant nutrient management because of the astounding capacity of phyto-nutrients remaining therein of being absorbed by leaves and other plant parts *vis-à-vis* their active ability in thorough transportation through out the plant body (Sreelekshmi *et al.,* 2025). Bringing all these critical points and suggestive alternatives, so far discussed, into account an experimental study was carried out through out the rainy season in the Indian Sundarbans to evaluate the agronomic and economic feasibility of integrating liquid fertilizers with conventional chemical nutrient management. The experimental approach involves a strategic reduction in the recommended doses of conventional fertilizers and supplementation through liquid formulations to evaluate their impact on crop growth and yield performance, quality attributes and plant nutrient uptake dynamics of rice. The overarching goal of this research was to evaluate whether the combined application of liquid and conventional fertilizers could sustain or enhance productivity relative to sole chemical fertilization, while concurrently improving grain quality and maintaining soil health. Moreover, evaluating the cost-effectiveness of these treatments will help in optimizing crop nutrition strategies to support long-term rice cultivation in CSZ of West Bengal.

MATERIALS AND METHODS

The field study was carried out over the 2023 and 2024 rainy seasons in the farmer's field of Rangabelia, Gosaba Block of West Bengal (22.15°N latitude and 88.84°E) located within the CSZ of West Bengal to assess the agronomic response and economic feasibility of combined application liquid fertilizers and conventional chemical fertilizers in transplanted paddy. The topography of the land is of medium low type. The experimental soil exhibited a clayey textural class, having a pH of 5.65, medium organic carbon content (0.52%) and available NPK (448.15, 16.2 and 150.46 kg ha^{-1}, respectively) within 0-30 cm soil layer. Meteorological observations during the crop growth period are presented in Fig. 1. The study was implemented using a randomized complete block design (RCBD) comprising six treatments consisting of T_1 [100% recommended dose of fertilizer (RDF_{NPK}) through conventional inorganic fertilizers]; T_2 [75% RDF_{NPK}+fortified nitrogen and phosphorus (7:21) @ 3.25 L ha^{-1}+$K_2S_2O_3$ @ 2.5 L ha^{-1}]; T_3 [50% RDF_{NPK} +Fortified NP (7:21) @ 3.25 L ha^{-1}+ $K_2S_2O_3$ @ 2.5 L ha^{-1}]; T_4 [75% RDF_{NPK}+Fortified NP (7:21) @ 6.5 L ha^{-1}+ $K_2S_2O_3$ @ 5.0 L ha^{-1}]; T_5 [50% RDF_{NPK}+Fortified NP (7:21) @ 6.5 L ha^{-1}+$K_2S_2O_3$ @ 5.0 L ha^{-1}] and T_6 [0% RDF_{NPK}, Absolute control] replicated four fold. The individual plot size was 5 m × 5 m. The RDF_{NPK} for rice (60-30-30 kg NPK ha^{-1}) was provided using urea, single super phosphate and muriate of potash (Ali *et al.,* 2025). Among the liquid fertilizers, fortified NP containing 7% N and 21% P_2O_5 by weight and potassium thiosulphate ($K_2S_2O_3$) containing 25% K_2O and 17% S by weight were tested. In each year, 21-day old rice seedlings of the cultivar 'Bidhan Suruchi' were transplanted at spacing of 20 cm between rows and 15 cm between plants during the third week of July and harvested in the last week of October. The entire quantity of phosphorus (P) and potassium (K) was applied during final land preparation,

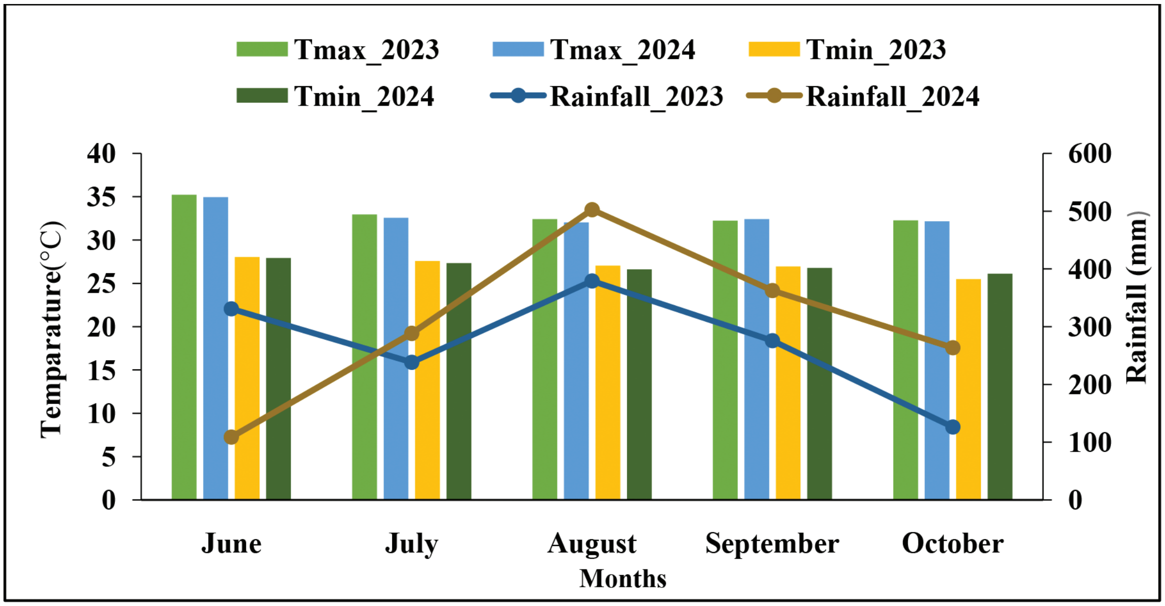

***Fig. 1.** Meteorological parameters during the crop growth period*

whereas, nitrogenous fertilizer was applied in three splits. Subsequently, liquid fertilizers after being mixed with the sticker were sprayed using a knapsack sprayer equipped with a WFN 040 flood jet nozzle using 500 L ha^{-1} of spray solution at three stages 30, 45 and 65 DAT according to the treatment details. The recommended agronomic practices for rice were followed throughout the crop growth period, except for the nutrient management treatments, which were imposed as per the experimental design. Abiding by the specific research protocol, observation on crop growth and yield components precisely plant height, biomass accumulation, tillers m^{-2}, panicle length, panicles m^{-2} and filled grains panicle^{-1} were recorded during the course of experimentation. After harvesting, grain yield was computed on a 14% moisture basis and converted to tonnes/ha; straw yield was measured after grain separation. Harvest index (HI) was estimated following the procedure described by Donald (1962). Grain quality attributes namely hulling (%), milling (%) and head rice recovery were worked out following the formula outlined by Khush *et al.* (1979).

$$\text{Hulling \%} = \frac{\text{Weight of brown rice}}{\text{Weight of rough rice}} \times 100 \quad ....(1)$$

$$\text{Milling \%} = \frac{\text{Weight of milled rice}}{\text{Weight of rough rice}} \times 100 \quad ....(2)$$

$$\text{Head rice recovery \%} = \frac{\text{Weight of head rice}}{\text{Weight of rough rice}} \times 100 ....(3)$$

Standard methods were followed for analysing the plant samples. The prevailing market prices taken for calculation (₹/t) were ₹20400 for rice and ₹2500 for paddy straw. The cost of cultivation was considered as ₹58250 ha^{-1} for rice. There remains no significant statistical difference within the years. Statistical analysis of the data was undertaken using analysis of variance (ANOVA) appropriate for a RCBD following the methodology outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Effect on growth, yield components and yield

Plant height and biomass accumulation was found to increase over time and it was maximum at 90 DAT across all treatments (Fig. 2). The highest plant height (81.62 and 109.23 cm) and dry matter accumulation (466.54 and 727.75 g m^{-2}) were observed under treatment T_4 (75% RDF_{NPK} + Fortified NP @ 6.5 L ha^{-1}+ $K_2S_2O_3$ @ 5.0 L ha^{-1}) at 60 and 90 DAT, respectively and these were significantly better than remaining treatments. Receiving relatively narrow treatment differences at 30 DAT may be attributed to the absence of liquid fertilizer application prior to this stage. The same treatment combination (T_4) also produced the maximum effective

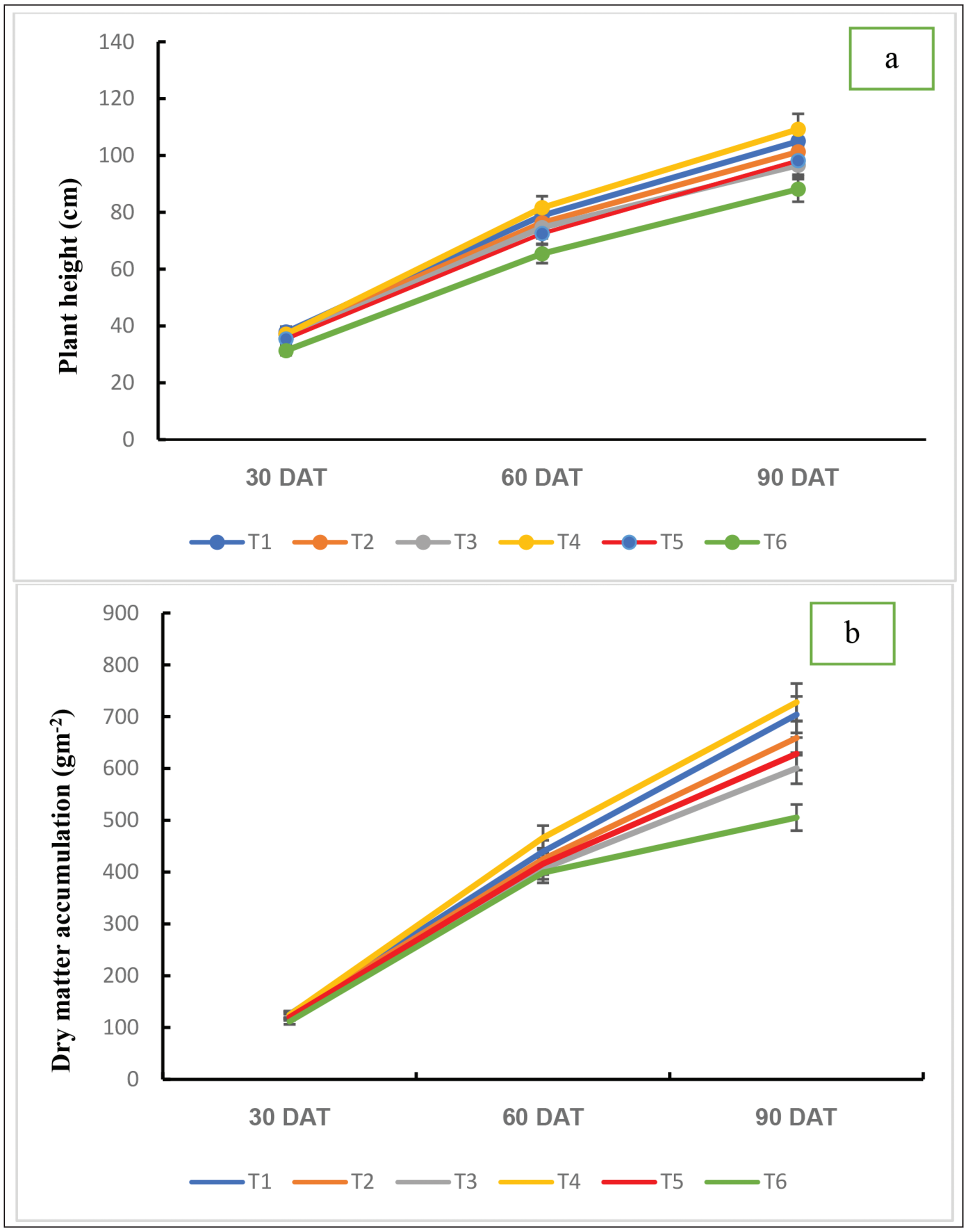

Fig. 2. *Effect of liquid fertilizers on growth parameters viz.(a) plant height (cm) and (b) dry matter accumulation (g m^{-2}) of transplanted Kharif rice*

tiller density (360.55 m^{-2}), indicating that partial substitution of soil-applied chemical NPK (25%) with foliar application of liquid fertilizers enhanced all crop growth attributes. Such enhancement occurred possibly due to consistent and uniform nutrient supply across different developmental stages of the crop. Regarding the yield attributing characters, the application of 75% RDF_{NPK} combined with foliar application of fortified NP @ 6.5 L ha^{-1} and $K_2S_2O_3$ @ 5.0 L ha^{-1} at respective growth stages (30, 45 and 65 DAT) resulted in the highest panicle density (265.35 m^{-2}), length of panicle (24.10 cm), filled grains panicle^{-1} (98.44) and grain filling percentage (84.02%). This response may be attributed to improved nutrient availability and efficient translocation of photosynthates during critical growth stages promoting sink development and enhanced grain filling (Mahmoodi *et al.,* 2020). The treatments had no significant effect on test weight, possibly because this trait is predominantly governed by genetic factors and less responsive to agronomic interventions (Mandi *et* *al.,* 2018). The treatment receiving foliar application of liquid fertilizers (Fortified NP @ 6.5 L ha^{-1} + $K_2S_2O_3$ @ 5.0 L ha^{-1}) with 75% RDF_{NPK} recorded the highest pooled grain yield (4.84 t ha^{-1}), straw yield (6.22 t ha^{-1}) and HI (43.76%). In general, treatment T_4 resulted in 14.69% enhancement in grain yield and 4.63% increase in straw yield over treatment receiving the full recommended dose of inorganic fertilizers (T_1); however, harvest index remained statistically comparable between this couple of treatments (Table 1).These findings indicate that 25% reduction in soil-applied NPK, when complemented with foliar application of liquid fertilizers (as in T_4), has been proved to be sufficient enough to sustain or enhance grain yield by synchronizing nutrient supply with crop demand. Foliar-applied N and P might support photosynthetic activity and sink strength, while K and S from $K_2S_2O_3$ may enhance translocation of assimilates, enzyme activation and grain filling efficiency; thereby improving overall nutrient use efficiency (Niu *et al.,* 2021; Sarwar *et al.,* 2022; Zenda *et al.,* 2021). This outcome synchronizes with the findings of Sreelekshmi *et al.* (2025) who opined that the foliar fertilization improves nutrient uptake and productivity in rice. As evident from the correlation heatmap (Fig. 4), significant positive corrections were observed among the several characters including plant height, dry matter yield, tiller density, panicle length, panicle density, filled grain/ panicle, grain filling percentage, grain yield and straw yield in the pooled analysis of two years. The pronounced reduction in the values of the parameters like growth, yield attributes as well as grain productivity obtained under the control treatment (T_6) clearly indicates that adequate and balanced nutrient management remains an essential prerequisite for sustaining rice productivity under coastal saline environments. The absence of ample nutrient supply adversely affected crop growth from the early vegetative stage to the reproductive phase, ultimately leading to significant yield loss (Sun *et al.,* 2024). In contrast, treatment T_4 exhibited 137% higher grain yield over the treatment to T_6, highlighting the cumulative and synergistic influence of balanced nutrient supply across different stages of the crop. These results demonstrate that continuous nutrient availability enhances vegetative growth, supports better panicle development and ensures efficient grain filling, thereby contributing to higher overall productivity in saline-prone environments.

Table 1. *Effect of liquid fertilizers on yield attributes and yield of transplanted Kharif rice (pooled data over the 2 years)*

Treatment	No. of effective tillers m^{-2}	Average panicle length (cm)	Panicle m^{-2}	Filled grains $panicle^{-1}$	Grain filling percent-age (%)	Test weight (g)	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})	Harvest index (%)
							Year I	Year II	Pooled		
T_1	341.56	22.85	249.30	93.27	81.87	21.36	4.25	4.19	4.22	5.82	42.03
T_2	319.24	20.95	234.18	84.52	77.49	21.11	4.05	4.11	4.08	5.66	41.89
T_3	281.36	19.42	208.73	78.47	69.61	21.07	3.60	3.51	3.55	5.19	40.65
T_4	360.55	24.10	265.35	98.44	84.02	21.56	4.80	4.89	4.84	6.22	43.76
T_5	301.68	19.01	217.60	81.61	72.19	21.09	3.78	3.85	3.81	5.35	41.63
T_6	207.57	18.26	178.37	62.18	55.27	20.99	2.11	1.98	2.04	4.31	32.23
SEm±	3.92	0.17	2.02	1.23	0.65	0.19	0.06	0.08	0.09	0.05	0.62
LSD (P=0.05)	11.93	0.53	6.15	3.75	1.98	NS	0.19	0.25	0.28	0.16	1.86

T_1: 100% RDF_{NPK}; T_2: 75% RDF_{NPK} + Fortified NP @ 3.25 L ha^{-1} + $K_2S_2O_3$ @ 2.5 L ha^{-1}; T_3:50% RDF_{NPK} + Fortified NP @ 3.25 L ha^{-1} + $K_2S_2O_3$ @ 2.5 L ha^{-1}; T_4: 75% RDF_{NPK} + Fortified NP @ 6.5 L ha^{-1} + $K_2S_2O_3$ @ 5.0 L ha^{-1}; T_5:50% RDF_{NPK} + Fortified NP @ 6.5 L ha^{-1} + $K_2S_2O_3$ @ 5.0 L ha^{-1} and T_6: Absolute control

The positive response observed under foliar application of liquid fertilizers may be particularly relevant under coastal saline conditions. In coastal saline soils, salinity stress often restricts nutrient availability and uptake by rice plants through osmotic effects and ionic imbalances (Rodríguez Coca *et al.,* 2023). Elevated

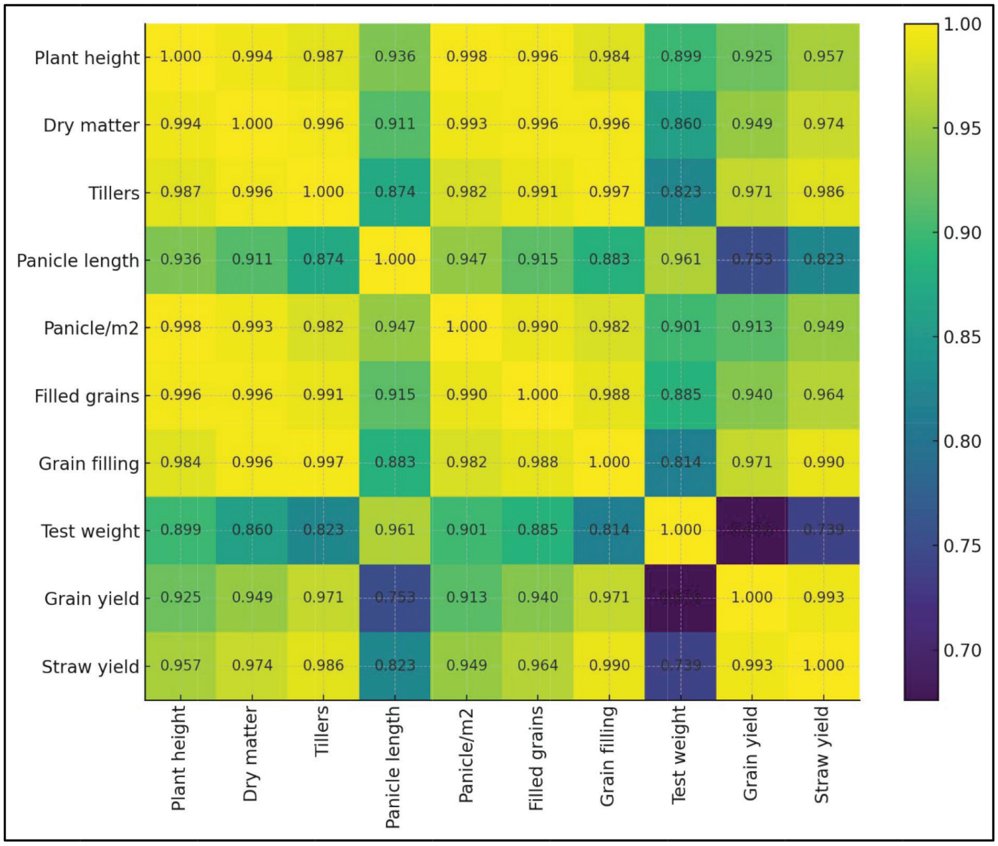

Fig. 4. *Correlation heat map among various plant growth, yield attributes and yield of rice*

levels of Na^+ and Cl^- ions interfere with the uptake of essential nutrients, thereby reducing nutrient acquisition efficiency and leading to nutrient deficiencies even under adequate soil nutrient availability, ultimately restricting plant growth and productivity (Zhao *et al.,* 2021). However, with the aim of increasing crop productivity, excessive and prolonged soil application of chemical fertilizers may contribute to secondary salinization (Stavi *et al.,* 2021). Therefore, to maintain an optimum nutrient supply while minimizing adverse effect on soil health, foliar application of liquid fertilizers has gained considerable attention as a supplementary fertilization approach, as it delivers nutrients directly to the above-ground plant parts (Bindraban *et al.,* 2015; Niu *et al.,* 2020).

Effect on grain quality

Rice grain quality is primarily determined by physical grain appearance, which largely influences both market value and consumer acceptance (Shen, 2025). The effect of liquid fertilizers application on grain quality parameters of rice was presented in Fig. 3. Statistical analysis revealed significant treatment effects for hulling (%), milling (%) and head rice recovery, whereas, kernel morphological traits remained uninfluenced. Kernel length and breadth exhibited negligible variation amongst treatments, resulting in a non-significant difference in the length-to-breadth (L/B) ratio remaining within a narrow range of 3.88 - 3.91 which indicates uniform grain type across treatments. Foliar application of liquid fertilizer (Fortified NP @ 6.5 L ha^{-1} + $K_2S_2O_3$ @ 5.0 L ha^{-1}) at 30, 45 and 65 DAT along with 75% recommend soil applied chemical fertilizer (25% reduction) recorded the highest hulling (75.66%), milling (68.25%) and head rice recovery (60.25%) percentage. This treatment showed statistical parity with full RDF_{NPK} through inorganic fertilizer in case of hulling and milling percentage. Head rice recovery is mainly an inherent trait of a variety, but it

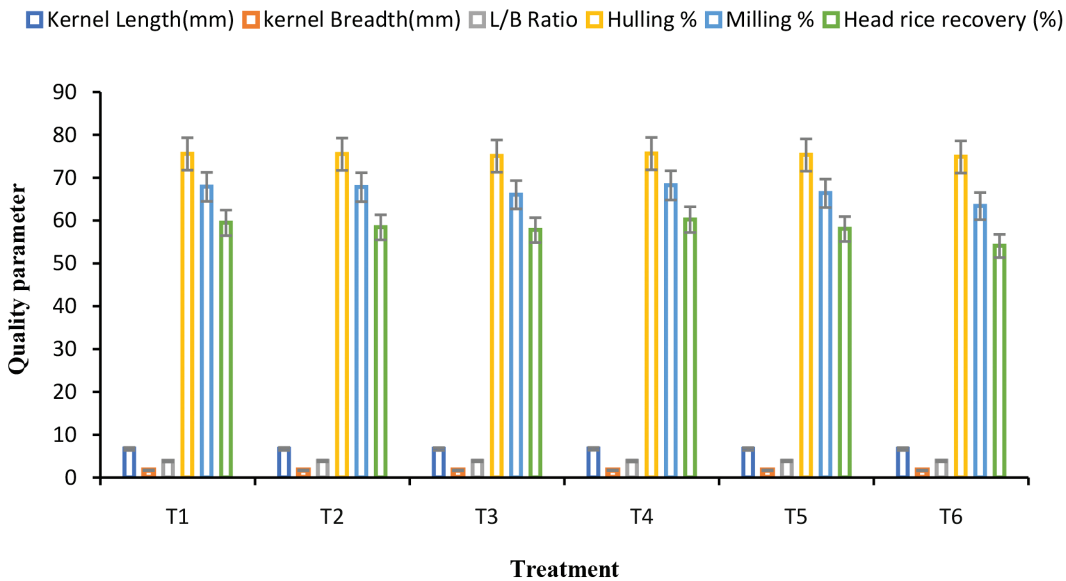

Fig. 3. *Effect of liquid fertilizers on quality parameters of transplanted Kharif rice*

is significantly influenced by nutrient management, as balanced fertilization improves grain filling, reduces chalkiness and enhances grain strength, resulting in higher head rice recovery (Joddar *et al.,* 2025; Shen, 2025). Variation in head rice recovery due to nutrient management has also been documented by Patra *et al.* (2024) and Joddar *et al.* (2025). The control treatment (T_6) yielded the lowest hulling, milling and recovery percentage indicating poor grain filling under nutrient deficiency. Similar results on superior grain quality through combined use of liquid and conventional fertilizers were witnessed by Mahmoodi *et al.* (2020) and Asha *et al.* (2025).

Effect on nitrogen, phosphorus and potassium uptake

Nutrient uptake in terms of nitrogen (N), phosphorus (P) and potassium (K) by rice responded significantly to foliar application of liquid fertilizers (Table 2). Among the treatments, T_4 (75% RDF_{NPK} combined with fortified NP @ 6.5 L ha^{-1} and $K_2S_2O_3$ @ 5.0 L ha^{-1}) resulted in the maximum total uptake of N (86.57 kg ha^{-1}), P (30.66 kg ha^{-1}) and K (131.30 kg ha^{-1}),

Table 2. *Effect of liquid fertilizers on nutrient uptake by transplanted Kharif rice (pooled data of two years)*

Treatment	Nutrient uptake								
	N (kg ha^{-1})			P (kg ha^{-1})			K (kg ha^{-1})		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1	55.17	28.51	83.68	17.13	11.64	28.77	17.55	110.58	128.13
T_2	51.84	26.17	77.65	15.79	9.10	24.89	16.20	104.69	120.89
T_3	44.60	22.26	66.86	12.74	7.95	20.69	13.80	94.87	108.67
T_4	57.02	29.55	86.57	18.57	12.09	30.66	18.29	113.01	131.30
T_5	47.24	24.61	71.85	14.14	8.02	22.16	14.92	100.04	114.96
T_6	24.00	17.20	41.20	12.90	4.73	17.63	7.20	72.67	79.87
SEm±	0.49	0.24	0.81	0.19	0.15	0.28	0.17	0.94	1.03
LSD (P=0.05)	1.48	0.72	2.44	0.59	0.45	0.89	0.52	2.86	3.08

T_1: 100% RDF_{NPK}; T_2: 75% RDF_{NPK} + Fortified NP @ 3.25 L ha^{-1} + $K_2S_2O_3$ @ 2.5 L ha^{-1}; T_3:50% RDF_{NPK} + Fortified NP @ 3.25 L ha^{-1} + $K_2S_2O_3$ @ 2.5 L ha^{-1}; T_4: 75% RDF_{NPK} + Fortified NP @ 6.5 L ha^{-1} + $K_2S_2O_3$ @ 5.0 L ha^{-1}; T_5:50% RDF_{NPK} + Fortified NP @ 6.5 L ha^{-1} + $K_2S_2O_3$ @ 5.0 L ha^{-1} and T_6: Absolute control significantly out performing the remaining treatments. Efficient translocation and better synchronization of nutrient supply with crop demand may be the probable reason behind substantial enhancement in crop biomass; as a result of which uptake of major nutrients was hiked under treatment T_4. Similar outcomes were documented by Alshaal and El-Ramady (2017), who observed that the combined application of inorganic fertilizers with supplementary nutrient sources significantly increased nutrient uptake and crop performance in rice. Treatments receiving reduced RDF in combination with nutrient-enriched liquid fertilizers showed improved uptake as compared to control, highlighting the effectiveness of liquid fertilizers application. This is in line with the recent outcomes of Lin *et al.* (2025) reporting enhancement of nutrient availability and plant uptake under the application of liquid fertilizers. Interestingly, treatment T_4 out performed the 100% RDF_{NPK} treatment (T_1), suggesting that partial substitution of conventional fertilizers with efficient liquid formulations can enhance nutrient use efficiency and sustain rice productivity. Comparable outcomes have been documented by Didawat *et al.* (2024) under long-term nutrient management studies.

Agro-economic aspects of rice cultivation

Maximum gross return amounting of ₹114286 ha^{-1} was observed with the combined application of liquid fertilizers, Fortified NP (6.5 L ha^{-1}) and $K_2S_2O_3$ (5.0 L ha^{-1}) along with 75% soil-applied RDF_{NPK} (T_4) and it was followed by (T_1), (T_2), (T_5) and (T_3) treatment. This enhancement in gross return was simply because of higher comparable grain and straw yield. Control plot (T_6) recorded the lowest gross return (₹52391 ha^{-1}) being even lower than the total cost of cultivation (Table 3), indicating rice production without nutrient management is economically unviable. The highest net return (₹43784 ha^{-1}) was registered under treatment T_4 exceeding that earned from the 100% RDF_{NPK} treatment (T_1). Higher gross return may be the probable reason. Considering the growing challenges of the over-dependency on chemical granular fertilizers and occurrence soil pollution, partial substitution (25%) of soil-applied fertilizers with liquid ones offers a promising sustainable and cost-effective strategy. Furthermore, the highest benefit-cost ratio (1.62) was achieved under T_4 treatment, followed by T_1 (1.59).

Table 3. *Effect of liquid fertilizers onproduction economics of transplanted Kharif rice (pooled data of two years)*

Treatments	Common cost (Rs. ha^{-1})	Treatment cost (Rs. ha^{-1})	Total cost (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
T_1	58250	5170	63420	100638	37218	1.59
T_2	58250	8027	66277	97382	31105	1.47
T_3	58250	6735	64985	85395	20410	1.31
T_4	58250	12252	70502	114286	43784	1.62
T_5	58250	10960	69210	91099	21889	1.32
T_6	58250	0	58250	52391	-5859	0.90

T_1: 100% RDF_{NPK}; T_2: 75% RDF_{NPK} + Fortified NP @ 3.25 L ha^{-1} + $K_2S_2O_3$ @ 2.5 L ha^{-1}; T_3:50% RDF_{NPK} + Fortified NP @ 3.25 L ha^{-1} + $K_2S_2O_3$ @ 2.5 L ha^{-1}; T_4: 75% RDF_{NPK} + Fortified NP @ 6.5 L ha^{-1} + $K_2S_2O_3$ @5.0 L ha^{-1}; T_5:50% RDF_{NPK} + Fortified NP @ 6.5 L ha^{-1} + $K_2S_2O_3$ @ 5.0 L ha^{-1} and T_6: Absolute control

CONCLUSION

The findings of the current investigation indicate that foliar supplementation with liquid fertilizers (Fortified NP @ 6.5 L ha^{-1} and $K_2S_2O_3$ @ 5.0 L ha^{-1}) applied at 30, 45 and 65 DAT, incombination with 75% RDF_{NPK} through soil application represents an efficient and economically viable nutrient management strategy. Integration of liquid fertilizers not only enhanced the productivity and profitability but also reduced dependency on conventional soil-applied chemical granular fertilizers by 25%, thereby minimizing their negative impact on soil health and environmental integrity. The results reinforce the potential of liquid fertilizers as a valuable component of nutrient management strategies, particularly in the stress prone zone like coastal saline ecosystems, where timely and effective nutrient supply is essential for improving yield and ensuring high economic returns.

CONFLICTS OF INTEREST

The authors declare no conflict of interest related to this publication.

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