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Effect of LCO-fortified biofertilizer and nano nitrogen on growth and nutrient use efficiency of rice (*Oryza sativa* L.)

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Abstract

A field experiment was conducted during *kharif* 2022 at the University of Agricultural Sciences, GKVK, Bengaluru to evaluate the Effect of LCO-fortified biofertilizer and nano nitrogen on growth and nutrient use efficiency of rice (*Oryza sativa* L.). The experiment was laid out in a Randomized Complete Block Design with seven treatments and three replications. Treatments consisted of different combinations of LCO-fortified biofertilizer, nano urea and mycorrhiza along with 100 and 75 per cent of the recommended dose of fertilizers. Application of 100% recommended NPK + LCO-fortified biofertilizer @ 10 kg ha⁻¹ along with foliar spray of nano urea @ 0.2% at 30 and 60 DAT recorded significantly higher plant height (77.1 cm), number of tillers plant⁻¹ (35.8) and number of leaves plant⁻¹ (71.5) at harvest. The same treatment also recorded earlier flowering (90.1 days) and physiological maturity (130.8 days). Higher nutrient use efficiency was observed with 75% recommended NPK + LCO-fortified biofertilizer @ 10 kg ha⁻¹ along with foliar spray of nano urea @ 0.2% at 30 and 60 DAT, which resulted in increased nitrogen (72.63 kg grain kg⁻¹ N), phosphorus (145.38 kg grain kg⁻¹ P₂O₅) and potassium use efficiency (181.71 kg grain kg⁻¹ K₂O), along with higher agronomic efficiency of nitrogen (18.99 kg kg⁻¹), phosphorus (38.02 kg kg⁻¹) and potassium (47.52 kg kg⁻¹). The results indicate that integration of LCO-fortified biofertilizer and nano nitrogen with recommended fertilizer levels can improve growth and nutrient use efficiency in rice cultivation.

Keywords: Rice, LCO-fortified biofertilizer, nano urea, nutrient use efficiency, agronomic use efficiency

Introduction

Rice (*Oryza sativa* L.) is one of the most important staple food crops in the world and serves as the primary source of calories for nearly half of the global population. Globally, rice is cultivated over approximately 162.06 million hectares with a production of about 496.40 million tonnes (Anon., 2021) [2]. Asia accounts for nearly 90 per cent of global rice production and consumption, while India ranks second in rice production with an area of 46.28 million hectares and a production of 129.47 million tonnes (Anon., 2022) [4]. In Karnataka, rice occupies about 13.85 lakh hectares with an average productivity of 3089 kg ha⁻¹ (Anon., 2022) [3]. With the global population projected to exceed eight billion, sustaining rice productivity under limited land, water and nutrient resources remains a major challenge.

Nitrogen is the most crucial nutrient determining rice growth and yield as it plays a vital role in chlorophyll formation, photosynthesis, tillering, leaf area development, grain formation and protein synthesis. However, nitrogen use efficiency (NUE) in rice ecosystems is relatively low due to losses through volatilization, denitrification, leaching and runoff. Excessive and imbalanced use of nitrogen fertilizers not only increases production costs but also contributes to environmental pollution and soil degradation. Nanotechnology has emerged as a promising approach to improve fertilizer efficiency. Nano-fertilizers with particle sizes ranging from 1-100 nm possess unique physicochemical properties such as high surface area and enhanced reactivity, enabling controlled and targeted nutrient release synchronized with crop demand (Giraldo *et al.*, 2014) [9]. Recent studies have reported that nano urea improves nitrogen use efficiency, plant growth and yield in rice (Patel *et al.*, 2024) [16]; Gondwal *et al.*, 2024 [10].

In addition to advanced fertilizer technologies, biofertilizers play an important role in sustainable nutrient management. Arbuscular mycorrhizal fungi enhance the uptake of relatively immobile nutrients such as phosphorus and micronutrients by extending the effective root surface area (Lehmann *et al.*, 2014)^[13]; (Wu *et al.*, 2024)^[20]. Lipo-chitoooligosaccharides (LCOs), also known as Myc factors, are signaling molecules produced by rhizobacteria and mycorrhizal fungi that regulate root development, microbial colonization and nutrient acquisition (Aamir *et al.*, 2020)^[1]. LCO-fortified biofertilizers stimulate root hair proliferation and improve plant-microbe interactions, thereby enhancing nutrient use efficiency. However, limited information is available on the combined application of LCO-fortified biofertilizers and nano nitrogen in rice under field conditions. Therefore, the present study was undertaken to evaluate their effect on growth, yield attributes and nutrient uptake of rice with the aim of improving nutrient use efficiency and promoting sustainable nutrient management.

Materials and Methods

The field experiment on the “Effect of LCO-fortified biofertilizer and nano nitrogen on growth and nutrient use efficiency of rice (*Oryza sativa* L.)” was conducted during Kharif 2022 at L-block, Integrated Farming System (IFS) demo unit, Zonal Agricultural Research Station, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bengaluru. The experimental site belongs to Eastern Dry Zone (Zone-V) of Karnataka and is located at 13°08' N latitude,

77°58' E longitude at an altitude of 930 m above mean sea level. The soil was red sandy loam (pH 5.92; EC 0.28 dS m⁻¹) with low organic carbon (0.46%), low nitrogen (263.5 kg ha⁻¹), high phosphorus (61.4 kg ha⁻¹) and medium potassium (225.4 kg ha⁻¹). The experiment was laid out in a Randomized Complete Block Design (RCBD) with seven treatments and three replications using paddy hybrid KRH-4 at a spacing of 30 × 10 cm and seed rate of 15 kg ha⁻¹. Treatments included 100% recommended NPK, 75% recommended NPK, Mycorrhiza, LCO-fortified biofertilizer @ 10 kg ha⁻¹, and foliar sprays of nano urea @ 0.2% at 30 and 60 DAT.

LCO-fortified biofertilizers contain *Bradyrhizobium* strains enriched with lipo-chitoooligosaccharides (LCOs) to enhance root growth, nutrient signaling and physiological efficiency, while nano nitrogen (nano urea) provides nitrogen in nanoparticle form for rapid foliar absorption and improved nitrogen use efficiency. Farmyard manure @ 10 t ha⁻¹ was applied before transplanting, and fertilizers were applied as per treatment schedule with 50% basal nitrogen and full P and K, and remaining nitrogen top-dressed at 30 DAT. Standard crop management practices including irrigation, gap filling, manual weeding, and nutrient management were followed. Growth parameters were recorded from five tagged plants at different growth stages, and soil and plant samples were analyzed for N, P, and K to determine nutrient use efficiency, and agronomic efficiency.

Results and Discussion

Table 1: Growth parameters and soil dehydrogenases activity at harvest of rice as influenced by LCO-fortified biofertilizer and nano nitrogen management

Treatments	Plant height (cm)	No. of tillers	No. of leaves	Soil dehydrogenase activity (ug TPF g ⁻¹ day ⁻¹)
T ₁ : 100% Rec. NPK as per PoP	56.9	30.2	58.3	32.09
T ₂ : 100% Rec. NPK + Mycorrhiza @ 10 kg ha ⁻¹	63.3	32.3	63.8	46.66
T ₃ : 100% Rec. NPK + LCO-fortified biofertilizer @ 10 kg ha ⁻¹	65.4	33.0	64.7	48.51
T ₄ : 100% Rec. NPK + LCO-fortified biofertilizer @ 10 kg ha ⁻¹ + foliar spray of nano urea @ 0.2% at 30 and 60 DAT	77.1	35.8	71.5	41.47
T ₅ : 75% Rec. NPK + Mycorrhiza @ 10 kg ha ⁻¹	59.2	31.3	63.3	63.27
T ₆ : 75% Rec. NPK + LCO-fortified biofertilizer @ 10 kg ha ⁻¹	64.8	32.6	64.6	67.05
T ₇ : 75% Rec. NPK + LCO-fortified biofertilizer @ 10 kg ha ⁻¹ + foliar spray of nano urea @ 0.2% at 30 and 60 DAT	68.3	35.0	65.7	49.07
F-test	*	*	*	*
S.Em.±	3.50	0.87	2.16	1.53
CD at 5%	10.78	2.67	6.66	4.72

Note: Rec. NPK- Recommended dose of nitrogen, phosphorus and potassium-125: 62.5: 50 kg N: P₂O₅: K₂O ha⁻¹ PoP- Package of practice LCO- Lipo-chito oligosaccharides DAT- Days after transplanting

Growth parameters

Growth parameters of rice were significantly influenced by the application of LCO-fortified biofertilizer and nano nitrogen management, and the results are presented in Table 1.

Among the treatments, T₄ (100% recommended NPK + LCO-fortified biofertilizer @ 10 kg ha⁻¹ + foliar spray of nano urea @ 0.2% at 30 and 60 DAT) recorded significantly higher plant height (77.1 cm), number of tillers (35.8 plant⁻¹) and number of leaves (71.5 plant⁻¹) compared with T₁ (100% recommended NPK as per PoP) which recorded 56.9 cm plant height, 30.2 tillers plant⁻¹ and 58.3 leaves plant⁻¹. However, T₄ was statistically on par with T₇ (75% recommended NPK + LCO-fortified biofertilizer @ 10 kg ha⁻¹ + nano urea spray).

The improved growth parameters under T₄ may be attributed to the synergistic effect of recommended fertilizers, LCO-fortified biofertilizer and foliar application of nano nitrogen. Lipo-chitoooligosaccharides act as signaling molecules that stimulate

root development, microbial activity and phytohormone regulation, thereby enhancing vegetative growth (Khan *et al.*, 2011)^[12]; (Minami *et al.*, 1996)^[15]. In addition, foliar application of nano nitrogen improves nitrogen availability and nitrogen use efficiency, resulting in enhanced photosynthetic activity, enzyme function and tiller production (Changmei *et al.*, 2002)^[8]; Hong *et al.*, 2005)^[11]. Similar improvements in growth and tillering of rice due to nano fertilizer application were reported by Benzon *et al.*, (2015)^[6] and Rathnayaka *et al.*, (2018)^[18].

Soil Dehydrogenase Activity

Soil dehydrogenase activity differed significantly among treatments (Table 1). The higher activity (67.05 µg TPF g⁻¹ soil day⁻¹) was recorded with T₆ (75% recommended NPK + LCO-fortified biofertilizer), which was on par with T₅ (75% recommended NPK + mycorrhiza). The lowest activity was

observed in T₁ (100% recommended NPK). Increased enzyme activity under LCO-based treatments may be attributed to enhanced microbial proliferation and rhizosphere activity. Dehydrogenase enzymes are indicators of microbial oxidative

metabolism and soil biological activity (Bolton *et al.*, 1985) [6]. Reduced chemical fertilizer levels combined with biofertilizers may stimulate microbial respiration and enzyme synthesis in soil.

Table 2: Days to 50 per cent flowering, days taken for physiological maturity and percentage lodging at harvest of rice as influenced by LCO-fortified biofertilizer and nano nitrogen management

Treatments	Days to 50% flowering	Days to physiological maturity	Scale
T ₁ : 100% Rec. NPK as per PoP	93.5	133.7	0
T ₂ : 100% Rec. NPK + Mycorrhiza @ 10 kg ha ⁻¹	92.5	132.8	0
T ₃ : 100% Rec. NPK + LCO-fortified biofertilizer @ 10 kg ha ⁻¹	91.3	131.6	1
T ₄ : 100% Rec. NPK + LCO-fortified biofertilizer @ 10 kg ha ⁻¹ + foliar spray of nano urea @ 0.2% at 30 and 60 DAT	90.1	130.8	2
T ₅ : 75% Rec. NPK + Mycorrhiza @ 10 kg ha ⁻¹	93.3	133.3	0
T ₆ : 75% Rec. NPK + LCO-fortified biofertilizer @ 10 kg ha ⁻¹	91.7	132.3	1
T ₇ : 75% Rec. NPK + LCO-fortified biofertilizer @ 10 kg ha ⁻¹ + foliar spray of nano urea @ 0.2% at 30 and 60 DAT	90.8	131.2	2
F-test	NS	NS	-
S.E.m.±	2.97	4.29	-
CD at 5%	-	-	-

Note: Rec. NPK- Recommended dose of nitrogen, phosphorus and potassium- 125: 62.5: 50

kg N: P₂O₅: K₂O ha⁻¹ PoP- Package of practice, LCO-Lipo-chito oligosaccharides, NS- Non-Significant, 0-2: 0% lodging; 3-4: 25% lodging; 5-6: 50% lodging; 7-8: 75% lodging; 9-10: 100% lodging

Days to fifty per cent flowering and physiological maturity

The number of days required to attain 50% flowering and physiological maturity of rice as influenced by LCO-fortified biofertilizer and nano nitrogen management is presented in Table 2. The treatments did not significantly influence the days to 50% flowering and physiological maturity as indicated by the non-significant F-test. However, numerically fewer days to 50% flowering (90.1 days) and physiological maturity (130.8 days) were recorded with T₄ (100% recommended NPK + LCO-fortified biofertilizer @ 10 kg ha⁻¹ + foliar spray of nano urea @ 0.2% at 30 and 60 DAT) compared with T₁ (100% recommended NPK as per POP), which recorded 93.5 and 133.7 days, respectively. A similar trend was observed with T₇ (75% recommended NPK + LCO-fortified biofertilizer + nano urea spray).

The relatively earlier flowering and maturity observed under treatments receiving LCO-fortified biofertilizer and nano nitrogen may be attributed to improved root growth, enhanced nutrient uptake and better physiological activity. Lipo-chitoooligosaccharides (LCOs) act as signaling molecules that stimulate root development and plant-microbe interactions, thereby enhancing nutrient absorption and plant growth

(Supanjani *et al.*, 2009) [19]. In addition, foliar application of nano nitrogen improves nitrogen use efficiency and metabolic processes, which may accelerate crop growth and development. Similar observations were reported by Midde *et al.* (2022) [14].

Lodging percentage at harvest

Lodging incidence at harvest as influenced by LCO-fortified biofertilizer and nano nitrogen management is presented in Table 2. Lodging was minimal across all treatments, with lodging scores ranging from 0 to 2 on the standard lodging scale. Slightly higher lodging scores (scale value of 2) were observed in T₄ (100% recommended NPK + LCO-fortified biofertilizer + nano urea spray) and T₇ (75% recommended NPK + LCO-fortified biofertilizer + nano urea spray) compared to other treatments. This may be attributed to increased plant height and vigorous vegetative growth resulting from improved nutrient availability and enhanced physiological activity. Greater biomass accumulation and plant stature may slightly increase susceptibility to lodging under field conditions. However, the overall lodging incidence remained negligible and did not adversely affect crop performance.

Table 3: Nutrient use efficiency of rice as influenced by LCO-fortified biofertilizer and nano nitrogen management

Treatments	Nutrient use efficiency (kg kg ⁻¹)		
	NUE	PUE	KUE
T ₁ : 100% Rec. NPK as per PoP	40.26	80.51	100.64
T ₂ : 100% Rec. NPK + Mycorrhiza @ 10 kg ha ⁻¹	45.02	90.05	112.56
T ₃ : 100% Rec. NPK + LCO-fortified biofertilizer @ 10 kg ha ⁻¹	52.93	105.86	132.32
T ₄ : 100% Rec. NPK + LCO-fortified biofertilizer @ 10 kg ha ⁻¹ + foliar spray of nano urea @ 0.2% at 30 and 60 DAT	56.41	112.90	141.12
T ₅ : 75% Rec. NPK + Mycorrhiza @ 10 kg ha ⁻¹	58.39	116.79	145.97
T ₆ : 75% Rec. NPK + LCO-fortified biofertilizer @ 10 kg ha ⁻¹	63.48	126.97	158.69
T ₇ : 75% Rec. NPK + LCO-fortified biofertilizer @ 10 kg ha ⁻¹ + foliar spray of nano urea @ 0.2% at 30 and 60 DAT	72.63	145.38	181.71

Note: Rec. NPK- Recommended dose of nitrogen, phosphorus and potassium- 125: 62.5: 50 kg N: P₂O₅: K₂O ha⁻¹ PoP- Package of practice LCO-Lipo-chito oligosaccharides NUE- Nitrogen use efficiency PUE- Phosphorus use efficiency KUE- Potassium use efficiency

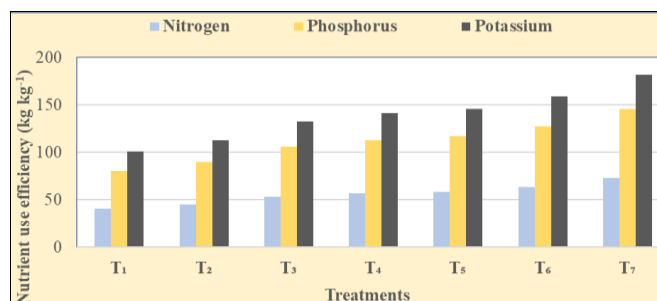


Fig 1: Nutrient use efficiency of rice as influenced by LCO-fortified biofertilizer and nano nitrogen management

Nutrient use efficiency

Nutrient use efficiency of rice as influenced by LCO-fortified biofertilizer and nano nitrogen management is presented in Table 3 and Fig. 1. The results indicated that nutrient use efficiency of nitrogen, phosphorus and potassium improved with the combined application of LCO-fortified biofertilizer and nano nitrogen.

Among the treatments, T₇ (75% recommended NPK + LCO-fortified biofertilizer @ 10 kg ha⁻¹ + foliar spray of nano urea @

0.2% at 30 and 60 DAT) recorded the higher nitrogen use efficiency (72.63 kg kg⁻¹), phosphorus use efficiency (145.38 kg kg⁻¹) and potassium use efficiency (181.71 kg kg⁻¹). This was followed by T₆ (75% recommended NPK + LCO-fortified biofertilizer @ 10 kg ha⁻¹) which recorded 63.48, 126.97 and 158.69 kg kg⁻¹ of NUE, PUE and KUE, respectively. The lower nutrient use efficiency was recorded in T₁ (100% recommended NPK as per PoP) with NUE, PUE and KUE values of 40.26, 80.51 and 100.64 kg kg⁻¹, respectively.

The higher nutrient use efficiency observed under T₇ may be attributed to the synergistic effect of reduced fertilizer dose, LCO-fortified biofertilizer and foliar application of nano nitrogen. Application of LCO enhances root growth, microbial activity and rhizosphere interactions, thereby improving nutrient uptake and translocation in plants. In addition, foliar application of nano urea provides nitrogen in a readily available form with reduced losses, leading to improved nitrogen utilization efficiency. Improved nitrogen availability further enhances phosphorus and potassium uptake and utilization in plants, thereby increasing overall nutrient use efficiency. Similar findings were reported by Qureshi *et al.* (2018) [17].

Table 4: Agronomic use efficiency of rice as influenced by LCO-fortified biofertilizer and nano nitrogen management

Treatments	Agronomic use efficiency (kg kg ⁻¹)		
	AUE _N	AUE _P	AUE _K
T ₁ : 100% Rec. NPK as per PoP	-	-	-
T ₂ : 100% Rec. NPK + Mycorrhiza @ 10 kg ha ⁻¹	4.76	9.53	11.92
T ₃ : 100% Rec. NPK + LCO-fortified biofertilizer @ 10 kg ha ⁻¹	12.67	25.34	31.68
T ₄ : 100% Rec. NPK + LCO-fortified biofertilizer @ 10 kg ha ⁻¹ + foliar spray of nano urea @ 0.2% at 30 and 60 DAT	16.18	32.38	40.48
T ₅ : 75% Rec. NPK + Mycorrhiza @ 10 kg ha ⁻¹	4.71	9.43	11.78
T ₆ : 75% Rec. NPK + LCO-fortified biofertilizer @ 10 kg ha ⁻¹	9.80	19.61	24.50
T ₇ : 75% Rec. NPK + LCO-fortified biofertilizer @ 10 kg ha ⁻¹ + foliar spray of nano urea @ 0.2% at 30 and 60 DAT	18.99	38.02	47.52

Note: Rec. NPK- Recommended dose of nitrogen, phosphorus and potassium- 125: 62.5: 50 kg N: P₂O₅: K₂O ha⁻¹ PoP- Package of practice LCO- Lipo-chito oligosaccharides AUE_N- Agronomic use efficiency of Nitrogen AUE_P- Agronomic use efficiency of Phosphorus AUE_K- Agronomic use efficiency of Potassium

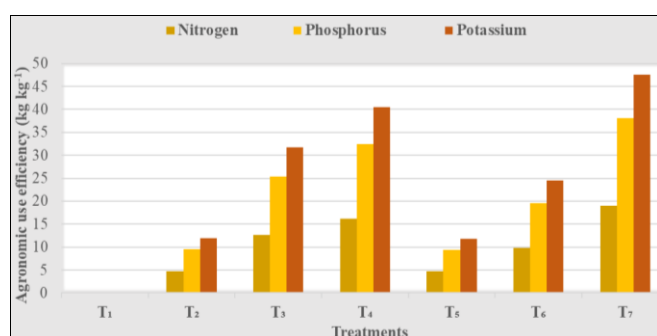


Fig 2: Agronomic use efficiency of rice as influenced by LCO-fortified biofertilizer and nano nitrogen management

Agronomic use efficiency

Agronomic use efficiency (AUE) reflects the increase in crop productivity obtained per unit of nutrient applied. The data on agronomic use efficiency of nitrogen, phosphorus and potassium as influenced by LCO-fortified biofertilizer and nano nitrogen management are presented in Table 4 and Fig. 2.

Among the treatments, T₇ (75% recommended NPK + LCO-fortified biofertilizer @ 10 kg ha⁻¹ + foliar spray of nano urea @ 0.2% at 30 and 60 DAT) recorded the higher agronomic use efficiency of nitrogen (18.99 kg kg⁻¹), followed by T₄ (100% recommended NPK + LCO-fortified biofertilizer + nano urea spray) (16.18 kg kg⁻¹), whereas the lower value (4.71 kg kg⁻¹)

was observed in T₅ (75% recommended NPK + mycorrhiza @ 10 kg ha⁻¹).

Similarly, the higher agronomic use efficiency of phosphorus (38.02 kg kg⁻¹) and potassium (47.52 kg kg⁻¹) was recorded under T₇, followed by T₄, which recorded 32.38 and 40.48 kg kg⁻¹ for phosphorus and potassium, respectively. The lower agronomic use efficiency of phosphorus (9.43 kg kg⁻¹) and potassium (11.78 kg kg⁻¹) was recorded in T₅.

The higher agronomic use efficiency observed under treatments receiving LCO-fortified biofertilizer and nano nitrogen may be attributed to improved root growth, enhanced nutrient uptake and better synchronization between nutrient availability and crop demand. LCO molecules stimulate root development and microbial activity in the rhizosphere, thereby improving nutrient absorption efficiency. In addition, foliar application of nano nitrogen provides nitrogen in a readily available form and reduces nutrient losses, ensuring sustained nutrient supply during critical growth stages. These factors improve source-sink relationships and ultimately enhance grain yield, resulting in higher agronomic use efficiency. Similar findings were reported by Chandana *et al.* (2021) [17].

Conclusion

The present study demonstrated that integration of LCO-fortified biofertilizer with nano nitrogen significantly improved growth attributes and nutrient use efficiency of rice. Application of

100% recommended NPK with LCO-fortified biofertilizer and nano urea spray enhanced plant growth, while 75% recommended NPK combined with LCO-fortified biofertilizer and nano nitrogen resulted in higher nutrient use efficiency. The results suggest that nano nitrogen and LCO-based biofertilizers can reduce chemical fertilizer requirement while maintaining crop productivity, thereby contributing to sustainable rice production.

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