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Nano fertilizers and its effect on nutrient use efficiency in rice

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Abstract
Rice is the most important agricultural crop which sustains more than 60% of the world's population as a dietary staple. Nano urea produced and patented by Indian Farmers Fertiliser Cooperative Limited [IFFCO] is developed to replace conventional urea and it can curtail the requirement by at least 50 percent and it will increase the nutrient use efficiency (NUE) by 80-90 percent. The main aim of the experiment was to assess the effect of nano fertilizers on the growth and yield of rice. The eight treatment combinations were T_1- Nano urea (foliar) at active tillering & panicle initiation, T_2 - Urea spray at active tillering & panicle initiation, T_3 - Nano Urea followed by nano K (foliar) at active tillering & panicle initiation, T_4- Nano K (foliar) at active tillering & panicle initiation, T_5- Nano NPK (foliar) at active tillering & panicle initiation, T_6 - 19:19:19 spray at active tillering & panicle initiation, T_7- 90:45:45 kg N, P_2O_5 & K_2O (KAU POP) and T_8- Absolute control. The results showed that the application of nano urea @ 4ml/L as foliar topdressing at active tillering & panicle initiation recorded statistically similar results as that of 90:45:45 kg N, P_2O_5 & K_2O (KAU POP) in terms of growth, yield and nutrient use efficiency in rice.

Keywords: Nano fertilisers, nutrient use efficiency, nano urea, Nano NPK, rice

Introduction
Rice (*Oryza sativa* L.) is the most important cereal crop providing more than 50 percent of the world's staple diet and 27 percent of energy supply. Conventional fertilizers are effective in nourishing high yielding varieties of crops because it provide essential nutrients in plant available form. However, unscrupulous application of fertilizers can result in soil quality deterioration due to many factors such as altering the soil physical and chemical properties and reduced microbial activity. Fertilizers can also cause pollution of water bodies by leaching and eutrophication. Soil application of fertilizers as basal and top dressing is the general practice in rice. Conventional granular urea is one of the most important nitrogenous fertilizers in the country, with nitrogen content of 46 percent but the efficiency of applied nitrogen is only 30-50 percent due to rapid chemical transformation, leaching and volatilization losses.
Nanotechonology resulted in production of nanoparticles of metabolically important nutrients which are designed to improve fertilizer uptake and thereby minimizing loss of nutrients. Nanofertilizers have high nutrient use efficiency due to its properties like high solubility, stability, targeted delivery and controlled release (Solanki *et al*., 2015) [10]. Nanofertilizers being foliar applied have high penetrative power and improves the crop growth, yield and nutrient use efficiency reducing fertilizer cost and emission risks (El-sadony *et al*., 2021) [3]. In this context, the current study was undertaken with the objective to evaluate nano nutrient formulations on growth, yield and nutrient use efficiency of rice.

Materials and Methods
The present study was carried out in Department of Agronomy, College of Agriculture, Vellanikkara during September 2022 to January 2023. The soil type of experimental site was sandy loam with pH 5.69 (moderately acidic), and organic carbon content of 0.55 percent. The primary nutrients *viz*., nitrogen (alkaline permanganate method), phosphorus (Olsen method) and potassium (neutral normal ammonium acetate method) content in the soil were 325 kg ha^{-1}, 40 kg ha^{-1} and 240 kg ha^{-1} respectively before starting the experiment.

The experiment was laid in randomized block design with eight treatment combinations replicated thrice. The eight treatment combinations were T_1- Nano urea (0.4% foliar) at active tillering & panicle initiation, T_2 - Urea (2% foliar) at active tillering & panicle initiation,T_3 - Nano Urea followed by nano K (0.4% foliar) at active tillering & panicle initiation, T_4- Nano K (0.4% foliar) at active tillering & panicle initiation, T_5- Nano NPK (0.4% foliar) at active tillering & panicle initiation, T_6 - 19:19:19 (1% foliar) at active tillering & panicle initiation, T_7- 90:45:45 kg N, P_2O_5 & K_2O (KAU POP) T_8- Absolute control [without manures & fertilisers]. The plot size was 5 m x 4 m and transplanting was done at a spacing of 20 cm x 10 cm at 20 days after sowing. The rice variety used was Uma (MO 16) developed by M. S. Swaminathan Rice Research Station, Moncombu under Kerala Agricultural University. In all treatments except absolute control, FYM @ 5 t/ha, full dose of P, half N & K will be applied as basal as soil application according to KAU POP (90:45:45 kg N, P_2O_5 & K_2O). IFFCO nano urea, Tag nano potash and Nano NPK (Tropical Agro) were applied @ 4 ml L^{-1} as top dressing at active tillering & panicle initiation. In T_3, nano K was given 5 days after nano urea application. Different nutrient use efficiencies were worked out to find out the efficiency of nanofertilisers used. Recovery efficiency is the proportion/ratio of nutrient uptake by the crop to nutrient applied (kg). Physiological efficiency is the ability of plants to transform acquired nutrients into economic yield and is impacted by partitioning, environment and management. It is the ratio of yield to total N uptake. Agronomic efficiency is expressed as increase in yield per unit of nutrient applied.

Results and Discussion

Taller plants were observed in nano urea foliar spray (T_1), 2% urea foliar (T_2) and T_7 (KAU POP) which were statistically on par with T_3 (nano urea followed by nano potash foliar spray) at harvest. The increased plant height in nanourea applied plants can be attributed to efficient release of nano-encapsulated nitrogen which in turn facilitated nutrient uptake, its transportation and absorption in plants (Midde *et al*. 2021) [8]. The plants in treatment nano urea as foliar spray (T_1), and T_7 (KAU POP) recorded statistically superior leaf area index (LAI) followed by treatments T_3 (nano urea followed by nano potash) and T_4 (nano K foliar spray) at 70 days after transplanting as well as at harvest. The application of nano urea spray @ 4 ml L^{-1} at active tillering and panicle initiation resulted in higher leaf area index can be due to improved nutrient absorption and utilization. The nanoscale composition facilitates more effective nutrient penetration and absorption through the leaves, fostering the expansion of leaves and overall canopy growth (Sharma *et al*., 2022) [1].

The treatments nano urea foliar spray (T_1), urea foliar spray (T_2), 19:19:19 foliar spray (T_6) and KAU POP (T_7) were found to be superior in number of tillers at 70 days after transplanting. The data revealed that total dry matter production in treatment KAU POP (8591 kg ha^{-1}) where total recommended dose of nitrogen is soil applied as basal and treatment T_1 (nano urea foliar spray), where 50 percent of the recommended dose of nitrogen is soil applied along with two foliar application of nano urea at active tillering and panicle initiation produced statistically similar results (8270 kg ha^{-1}). The treatment absolute control (T_8) recorded the lowest dry matter production of 4267 kg ha^{-1}. At 70 days after transplanting, the highest recorded value of chlorophyll (2.101 mg/g) was observed in treatment KAU POP, and this value is statistically comparable to those of treatments T_1, T_3, and T_6.

Yield attributes in rice were significantly influenced by different treatments. The treatment KAU POP, produced highest number of panicles per m^2 (350.7 panicles m^{-2}) which was on par with treatment nano urea foliar spray (T_1) (335 panicles m^{-2}). This result is in consistent with Attri *et al*. (2022) [1] and may be due to the fact that nutrition in the early stages of plant life provided enough time for good nutrition which gave greater chance of increasing number of panicles and filled grains (Jassim *et al*., 2019) [6]. The number of filled grains per panicle was found to be higher in treatment KAU POP (110) which was found to be statistically on par with treatment nano urea foliar spray (105). It might be due to increased enzyme activity such as those required for the CO_2 assimilation pathway and chlorophyll biosynthesis, which could result in the production and transportation of photosynthates to sink which in turn increased the number of grains per panicle (Gewaily *et al*., 2019) [4]. The average 1000 grain weight was 24.42 g.

KAU POP (T_7) recorded highest grain yield of 4173 kg ha^{-1}, comparable to the yield of 3981 kg ha^{-1} in treatment nano urea foliar spray (T_1). Treatment KAU POP recorded highest straw yield of 4289 kg ha^{-1}, which was comparable to the yields obtained from treatments T_1, T_2, T_4, T_5 and T_6. Synergistic interaction between conventional and nanofertilizers was observed by Benzon *et al.* (2015) [2] and this leads to better absorption of nutrients, accumulation of photosynthates and translocation to economic parts resulted in increased grain yield. The higher yield obtained could also be a reflection of higher chlorophyll content as suggested by Hopkins and Hurner (2008) [5]. The highest harvest index, was observed in KAU POP (0.49), and is comparable to the harvest indices of treatments T_1, T_2, T_3, T_4 and T_5. This was due to the positive effect of nano nitrogen in production and partitioning of photosynthates towards sink.

Nutrient use efficiency is an important concept for evaluating the efficiency of fertilisers applied with respect to crop production. Highest agronomic efficiency (of nitrogen fertilizer) and recovery efficiency was recorded in nano urea foliar spray (T_1) (48.30 kg kg^{-1}) followed by the treatment nano urea followed by nano potash (T_3) (37.64 kg kg^{-1}). The treatment nano urea followed by nano potash recorded higher physiological efficiency (59.25 kg kg^{-1}). The improved performance of rice treated with two nano sprays can be attributed to the lower dosage of nano fertilisers applied as well as its effect on higher production in terms of yield. The features of nano fertilisers facilitate its targeted uptake, allowing them to penetrate deep into the leaves and thereby enhanced nutrient use efficiency. Nano fertilizers, in particular, exhibit superior transport and nutrient delivery through plasmodesmata, which are nano-sized channels (50-60 nm) between cells, as observed by Mahanta *et al*. (2020) [7]. The results of the study revealed that the application of nano urea @ 4 ml L-1 at active tillering and panicle initiation along with soil application of K at panicle initiation was better in terms of yield and nutrient use efficiency and it was on par with treatment applied with KAU POP (90: 45:45 kg ha^{-1}).

Table 1: Biometric parameters and Chlorophyll content as influenced by different treatments

Treatments		Plant height (cm) At harvest	Leaf Area Index (LAI) At harvest	No. of tillers per m^2	Total DMP* (kg ha^{-1})	Chlorophyll content (mg g^{-1})
T_1	Nano urea (foliar) at active tailoring (AT)& panicle initiation (PI)	98.1	4.58	462.67	10670	1.67
T_2	Urea (2 percent foliar) at AT and PI	97.5	4.04	449.33	9537	1.41
T_3	Nano urea fb nano K (foliar) at AT and PI	95.6	4.24	429.33	9397	1.76
T_4	Nano K at AT and PI	93.5	4.22	424.0	9262	1.30
T_5	Nano NPK (foliar) atAT and PI	93.3	3.98	426.67	9135	1.41
T_6	19:19:19 (one percent foliar) at AT and PI	94.1	4.07	457.33	9052	1.88
T_7	90:45:45 kg N, P2O5 & K2O (POP, KAU)	100.1	4.73	472.0	11027	2.10
T_8	Absolute control	88.6	2.18	377.33	7307	0.99
S.Em (±)		0.966	0.12	8.14	335.144	0.155
CD (0.05)		2.99	0.364	24.689	1016.55	0.47

*DMP- Dry Matter Production

Table 2: Yield attributes and yield of rice as influenced by different treatments

Treatments		No. of panicles/m^2	No. of filled grains/panicle	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index
T_1	Nano urea (foliar) at AT and PI	335.0	105.8	3981	4289	0.48
T_2	Urea (2 percent foliar) at AT and PI	324.7	100.3	3388	4014	0.46
T_3	Nano urea *fb* nano K (foliar) at AT and PI	321.0	99.7	3500	3784	0.48
T_4	Nano K at AT and PI	314.3	95.3	3277	3913	0.45
T_5	Nano NPK (foliar) at AT and PI	318.3	94.3	3226	3866	0.45
T_6	19:19:19 (1 percent foliar) at AT and PI	322.0	101.2	3133	3898	0.44
T_7	90:45:45 kg N, P_2O_5 & K_2O (POP, KAU)	350.7	110.1	4173	4417	0.49
T_8	Absolute control	282.3	89.3	1800	2466	0.42
S.Em (±)		5.711	1.68	1.68	132.59	0.011
CD (0.05)		17.322	5.119	5.119	402.19	0.034

Table 3: Nitrogen use efficiency as influenced by different treatments

Treatments		Agronomic efficiency (kg kg^{-1})	Physiological efficiency (kg kg^{-1})	Recovery efficiency (kg kg^{-1})
T_1	Nano urea (foliar) at AT and PI	48.30	51.84	93.42
T_2	Urea (2 percent foliar) at AT and PI	29.31	50.35	59.40
T_3	Nano urea *fb* nano K (foliar) at AT and PI	37.64	59.25	67.02
T_4	Nano K at AT and PI	16.42	51.45	32.22
T_5	Nano NPK (foliar) at AT and PI	31.69	52.96	64.54
T_6	19:19:19 (1percent foliar) at AT and PI	28.44	47.31	60.24
T_7	90:45:45 kg N, P_2O_5 & K_2O (POP, KAU)	26.38	51.64	51.75
T_8	Absolute control	-	-	-

Conclusion

The study found that plants treated with nano urea foliar spray (T_1) and KAU POP (T_7) exhibited superior growth and yield metrics. These treatments resulted in taller plants, higher leaf area indices, and greater dry matter production, attributed to the efficient nutrient uptake facilitated by nano-encapsulated nitrogen. The number of tillers, panicles per square meter, and filled grains per panicle were significantly higher in these treatments, contributing to increased grain yields. The highest grain and straw yields were recorded in the KAU POP treatment, closely followed by the nano urea spray treatment. Nano fertilizers demonstrated enhanced nutrient use efficiency, with T_1 showing the highest agronomic efficiency. This improved performance underscores the potential of nano fertilizers in optimizing crop production and nutrient management.

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