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Nano and water-soluble fertilizers on growth and yield of transplanted rice (*Oryza sativa* L.)

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Abstract
A field experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani during November 2023 to March 2024 to assess the effect of nano-N, nano-P and water soluble fertilizers on the growth and yield of lowland rice. The field experiment was laid out in Randomized Complete Block Design (RCBD). The study comprised of 8 treatments and replicated thrice with Uma (Mo 16) as the test variety. The treatments were T_1: Nano-urea (0.4%) at active tillering (AT) + Nano-urea (0.4%) at panicle initiation (PI), T_2: Nano-DAP (0.4%) at AT + Nano-DAP (0.4%) at PI, T_3: Potassium nitrate (0.5%) at AT + Potassium nitrate (0.5%) at PI, T_4: Nano-urea (0.4%) at AT + Nano-DAP (0.4%) at PI, T_5: Nano-urea (0.4%) at AT + PSAP (0.4%) at PI, T_6: Nano-urea (0.4%) at AT + Potassium nitrate (0.5%) at PI, T_7: Urea (2.0%) at AT + DAP (2.0%) at PI and T_8: KAU POP. In all the treatments except T_8, the recommended dose of nitrogen and phosphorus were reduced by 25 per cent and 50 per cent respectively. The treatment T_5, resulted in higher grain yield, productive tillers per square metre, grains per panicle, tillers per square metre, leaf area per hill, LAI and flag leaf area per hill.

Keywords: Rice, nano and water-soluble fertilizer, foliar application, growth and yield

Introduction

Rice (*Oryza sativa* L.) is one of the most important staple crops in the world, feeding more than half of the global population. It provides a major source of energy, carbohydrates, and essential nutrients for billions of people, particularly in Asia, Africa, and Latin America. According to Siddiq (2000) [34], India requires 450 million tonnes of food grains by 2050 to meet the food demands of 1.6 billion people. In the basket of food grains, rice holds a unique position as its demand is on a steady rise and is expected to grow by more than 50 per cent in the decades to come (Zeigler, 2012) [42]. Balanced and rationalized nutrient management in rice cultivation is essential for ensuring optimal plant growth, yield, and soil health. Rationalizing nutrient management in tune with the crop requirement and soil fertility is crucial for improving productivity and sustainability. A balanced approach ensures that rice plants receive adequate nutrients throughout their growth cycle, promoting strong root development, healthy foliage, and effective grain filling. Effective nutrient management plays a key role in achieving food security and ensuring the availability of rice for future generations. Ultimately, rational nutrient management supports healthier soil, higher yields, and long-term food security.

Foliar nutrition, when used in addition to the recommended soil fertilizer application, is highly beneficial as it provides essential nutrients when the roots cannot meet the crop's demands during critical growth stages. Appropriate crop management strategies is the key for enhancing input use efficiency in rice. Foliar nutrition is one such strategy which ensures better utilization of the applied nutrients by the crop. Plant leaves being the organ of photosynthesis is considered to be the important determinant and characterized for higher photosynthetic capacities (Asana, 1968) [4]. Water-soluble fertilizers are more effective source of nutrients for foliar application (Vibhute, 1998) [39]. Recently, a new generation of water-soluble fertilizers specifically designed for foliar feeding has been introduced.

These fertilizers come in various N, P, and K ratios and are highly water-soluble, and are usually included under the umbrella of specialty fertilizers. Nanofertilizers, can enter the cell wall since the nanoparticles with a diameter smaller than the pore size of the plant cell wall can easily pass through the wall and reach the plasma membrane (Navarro *et al*., 2008) [27].

Thus integrating water-soluble and nanofertilizers for foliar nutrition in rice could be considered as a viable and sustainable approach for enhancing crop productivity. Keeping the above in view, the present study was undertaken to assess the possibility of increasing the productivity of lowland rice by integrating nano and water-soluble fertilizers.

Materials and Methods

The field experiment was conducted in a sandy clay loam soil at the Instructional Farm, College of Agriculture, Vellayani during November 2023 to March 2024. The soil of the experimental site was moderately acidic in reaction (pH-5.73), normal in electrical conductivity (EC- 0.165 dS m^{-1}), medium in organic carbon (1.35%) and available nitrogen (351.23 kg ha^{-1}), low in available phosphorus (8.96 kg ha^{-1}) and potassium status (102.14 kg ha^{-1}). The experiment was laid out in a randomized complete block design (RCBD) and the medium duration variety Uma (Mo 16) was chosen. The study comprised of 8 treatments and replicated thrice. Treatment details were as follows; T_1: Nano-urea (0.4%) at active tillering (AT) + Nano-urea (0.4%) at panicle initiation (PI), T_2: Nano-DAP (0.4%) at AT + Nano-DAP (0.4%) at PI, T_3: Potassium nitrate (0.5%) at AT + Potassium nitrate (0.5%) at PI, T_4: Nano-urea (0.4%) at AT + Nano-DAP (0.4%) at PI, T_5: Nano-urea (0.4%) at AT + PSAP (0.4%) at PI, T_6: Nano-urea (0.4%) at AT + Potassium nitrate (0.5%) at PI, T_7: Urea (2.0%) at AT + DAP (2.0%) at PI and T_8: KAU POP. In the treatments, T_1 to T_7, the recommended dose of N and P were reduced by 25 per cent and 50 per cent respectively. Application of farmyard manure (FYM), potassium (K) and all other cultural practices were done as per the KAU package of practices recommendations (KAU POP) (KAU, 2016) [18]. Foliar application was given at active tillering and panicle initiation stages, in accordance with the treatments envisaged. Farmyard manure was applied as basal at the rate of 5 t ha^{-1} and incorporated. Lime was applied at the rate of 600 kg ha^{-1} (350 kg ha^{-1} as basal and 250 kg ha^{-1} at 30 days after transplanting). The major nutrients, *viz.*, N, P and K were supplied as urea, rock phosphate and MOP based on the nutrient recommendation of 90:45:45 kg NPK ha^{-1}. Half the dose of nitrogen, entire dose of phosphorus and half potassium were applied basally, one week after transplanting. While the remaining nitrogen was split into two and applied as half at active tillering and half at panicle initiation, the remaining potassium was applied at panicle initiation stage. Foliar application of the various nutrient sources was done at active tillering and panicle initiation stages as per the treatments along with an adjuvant. Twenty-two days old seedlings were transplanted at the rate of 2 seedlings per hill maintaining a spacing of 20 cm x 10 cm, at a depth of 3-4 cm. Foliar nutrition was done as per treatments, following the procedure of Fageria *et al*. (2009) [10]. Nano-urea, nano-DAP and Potassium Salt of Active Phosphorus (PSAP) were sprayed at 0.4 per cent concentration each, potassium nitrate was sprayed at 0.5 per cent concentration and urea and DAP were sprayed at 2 per cent concentration each. The nutrient sources were sprayed along with an adjuvant (1 mL per 10 litres of spray fluid) adopting high volume spraying at a spray volume of 500 L ha^{-1}. Spraying was done after 3.00 p.m. under calm atmospheric conditions. The growth and yield attributes were recorded following standard procedures.

Results and Discussion

1. Effect of foliar nutrition on growth and growth attributes of rice

1.2 Plant height

Foliar nutrition with the different sources, including nano and water soluble fertilizers had significant effect on the plant height of rice at panicle initiation, flowering and harvest stages. At panicle initiation, foliar nutrition with nano-urea (0.4%) at active tillering (AT) followed by nano-DAP (0.4%) at panicle initiation (PI) (T_4) resulted in taller plants (98.04 cm). It was comparable with T_3 (97.45), T_6 (96.00 cm), T_5 (94.55 cm) and T_7 (93.67 cm). At flowering stage, plants were observed to be taller (111.10 cm) with T_3 (0.5% KNO_3 at AT + PI) and it was statistically at par with T_5 (110.66 cm), T_4 (109.60 cm) and T_7 (109.20 cm). At harvest stage, taller plants (112.75 cm) were observed in response to foliar nutrition with 0.4 per cent each of nano-urea and PSAP at AT and PI stages respectively (T_5). However, it was comparable with T_3 (112.41 cm), T_7 (111.57 cm) and T_4 (110.68 cm). At all these growth stages, foliar nutrition with nano-urea (0.4%) at AT+ PI (T_1) was noted in resulting comparatively shorter plants (Table 1).

Plant height showed greater improvement when nanofertilizers were combined with conventional fertilizers, even at lower application rates. The increase in plant height of rice achieved through foliar sprays of nano-urea (0.4%) could be attributed to the role of nitrogen in enhancing crop growth, elongating internodes, boosting photosynthesis and metabolism, and improving the production of assimilates, which ultimately led to better overall crop growth as suggested by Benzon *et al*. (2015) [6]. Nano-urea has been reported to supply nitrogen to plants or assist in the absorption and transport of available nutrients, leading to improved crop growth (Ham *et al*., 2013) [12]. According to a study by Kothari *et al*. (2023) [19], taller plants were observed when nano-nitrogen was applied as a foliar spray compared to control plots without the nano-nitrogen spray. The application of nano-DAP at the panicle initiation stage might have enhanced the phosphorus availability, which is essential for the sustenance of healthy root growth and overall plant vigor (Maloth *et al*., 2024) [23]. The positive influence of foliar application of potassium nitrate (KNO_3) in enhancing potassium availability directly to the leaves, improving nutrient uptake and usage during key growth stages have been reported by Jothi *et al*. (2019) [16]. Application of KNO_3 at tillering and panicle initiation stages might have coincided with the period of highest nutrient demand, leading to taller plants and improved yield characteristics. Similar observations were made by Hasan *et al*. (2020) [13]. Application of KNO_3 during crucial growth stages like tillering and panicle initiation might have also optimized the nutrient assimilation by plants, leading to increased plant height (Mahmoodi *et al*., 2020) [22].

1.2 Leaf area index

Leaf area index of rice at flowering stage was highest (5.74) with foliar nutrition of nano-urea (0.4%) at AT followed by PSAP (0.4%) at PI (T_5), followed by a LAI of 5.51 with foliar application of 2 per cent urea at AT + 2 per cent DAP at PI (T_7). Nano-DAP (0.4%) AT and PI stages (T_2) was noted to result relatively lower leaf area index. At harvest stage, higher leaf area index (3.91) was observed with nano-urea (0.4%) at AT followed by PSAP (0.4%) at PI stages (T_5). It was comparable with T_4 (3.87), T_3 (3.86) and T_7 (3.71). Comparatively lower LAI was observed in KAU POP (Table 2).

According to Sharma *et al*. (2022) [32] nano-urea spray increased the LAI by improving nutrient uptake and utilization. The nanoscale formulation allows for better penetration and absorption of nutrients through leaves, promoting leaf expansion and overall canopy development. This supports earlier findings that demonstrated a positive correlation between nano-urea and increased LAI. The present study also highlighted the potential of this innovative approach to sustainably boost crop growth. Nano-urea has also been shown to positively affect the physiological traits of rice. Devi and Luikham (2018) [9] observed an increase in leaf area and LAI resulting from the interaction between phosphorus and potassium in black aromatic rice. As a mobile element, potassium plays a crucial role in expanding leaf area by promoting leaf expansion, increasing the number of leaves, and activating enzymes, all of which contribute to a larger leaf area and LAI, thereby increase in overall plant growth (Al-Furtuse *et al*., 2019) [2].

1.3 Flag leaf area per hill

The highest flag leaf area (52.08 cm^2) was observed with the application of 0.4 per cent nano-urea at AT stage followed by 0.4 per cent PSAP at PI stage (T_5). This was followed by T_7 (47.72 cm^2), which in turn remained comparable with T_6 (45.65 cm^2). Foliar nutrition with nano-urea (0.4% each) at AT and PI stages (T_1) resulted in smaller flag leaves as evidenced by the lesser values of flag leaf area per hill (Table 3). This could possibly be due to the ample supply of nitrogen, which led to an increase in the length of the flag leaf. Similar findings were reported by Bahmaniar and Ranjbar (2007) [5] and Siavoshi *et al*. (2011) [33]. The application of phosphorus significantly enhances net photosynthetic rate in rice flag leaves, with optimal levels resulting in increased chlorophyll content and improved stomatal conductance. Th effect of PSAP could be due to the positive interaction between potassium and phosphorus leading to enhanced physiological efficiency, resulting in larger flag leaf area as pointed out by Kalaignan (2024) [17].

1.4 Total dry matter production

Application of urea (2%) at active tillering followed by DAP (2%) at panicle initiation stages (T_7), resulted in higher total dry matter production (11102 kg ha^{-1}). This was comparable with KAU POP (10839 kg ha^{-1}), T_5 (10835 kg ha^{-1}) and T_6 (10801 kg ha^{-1}). Total dry matter production of rice was noted to be comparatively lesser in response to foliar nutrition with 0.4 per cent each of nano-urea at active tillering and panicle initiation stages (T_1) (Table 3). At active tillering stage, foliar application of urea could have supported vegetative growth by boosting nitrogen uptake, leading to higher chlorophyll content and, consequently, improved photosynthetic rates. As the plant approached the PI stage, foliar nutrition with DAP might have ensured sufficient phosphorus availability, which is crucial for energy transfer and root development, thus further aiding in efficient nutrient uptake and dry matter accumulation. According to Singh and Modgal (1979) [35] split application of nitrogen during key growth phases (like tillering and panicle initiation) led to more efficient use of the nutrient, resulting in increased biomass production. By ensuring nitrogen availability at critical stages of growth, the rice plants produced more leaves and stems, which got translated into greater dry matter accumulation.

Table 1: Effect of foliar nutrition on plant height of rice, cm

Treatment	Plant height			
	Active tillering	Panicle initiation	Flowering	Harvest
T_1 – Nano Urea (0.4%) at AT and PI	73.06	84.78	97.08	99.43
T_2 – Nano DAP (0.4%) at AT and PI	80.36	89.42	98.98	102.66
T_3 – KNO_3 (0.5%) at AT and PI	81.18	97.45	111.10	112.41
T_4 – Nano Urea (0.4%) at AT + Nano DAP (0.4%) at PI	79.75	98.04	109.60	110.68
T_5 – Nano Urea (0.4%) at AT + PSAP (0.4%) at PI	75.37	94.55	110.66	112.75
T_6 – Nano Urea (0.4%) at AT + KNO_3 (0.5%) at PI	72.70	96.00	104.56	106.85
T_7 – Urea (2%) at AT + DAP (2%) at PI	74.95	93.64	109.20	111.75
T_8 – KAU POP	76.06	90.18	102.76	108.78
SEm(±)	2.07	1.90	1.38	1.23
CD (0.05)	NS	5.718	4.186	3.726

AT- Active tillering; PI- Panicle initiation; NS- Not significant

Table 2: Effect of foliar nutrition on leaf area index of rice

Treatment	Leaf area index			
	Active tillering	Panicle initiation	Flowering	Harvest
T_1 – Nano Urea (0.4%) at AT and PI	3.36	4.18	4.74	3.59
T_2 – Nano DAP (0.4%) at AT and PI	3.57	4.23	4.73	3.63
T_3 – KNO_3 (0.5%) at AT and PI	3.68	4.41	4.91	3.86
T_4 – Nano Urea (0.4%) at AT + Nano DAP (0.4%) at PI	3.75	4.67	5.06	3.87
T_5 – Nano Urea (0.4%) at AT + PSAP (0.4%) at PI	3.43	3.65	5.74	3.91
T_6 – Nano Urea (0.4%) at AT + KNO_3 (0.5%) at PI	3.31	4.50	5.03	3.50
T_7 – Urea (2%) at AT + DAP (2%) at PI	3.44	3.50	5.51	3.71
T_8 – KAU POP	3.64	3.45	5.06	3.51
SEm(±)	0.18	0.74	0.05	0.07
CD (0.05)	NS	NS	0.153	0.200

AT- Active tillering; PI- Panicle initiation; NS- Not significant

Table 3: Effect of foliar nutrition on flag leaf area per hill and total dry matter production

Treatment	Flag leaf area per hill (cm^2)	Total dry matter production (kg ha^{-1})
T_1 – Nano Urea (0.4%) at AT and PI	33.48	8780
T_2 – Nano DAP (0.4%) at AT and PI	37.32	8812
T_3 – KNO_3 (0.5%) at AT and PI	40.53	9235
T_4 – Nano Urea (0.4%) at AT + Nano DAP (0.4%) at PI	41.39	9343
T_5 – Nano Urea (0.4%) at AT + PSAP (0.4%) at PI	52.08	10835
T_6 – Nano Urea (0.4%) at AT + KNO_3 (0.5%) at PI	45.65	10801
T_7 – Urea (2%) at AT + DAP (2%) at PI	47.72	11102
T_8 – KAU POP	42.91	10839
SEm(±)	0.88	217
CD (0.05)	2.662	658.0

AT- Active tillering; PI- Panicle initiation

2. Effect of foliar nutrition on yield attributes and yield

2.1 Productive tillers per square metre

Among the different treatments, foliar nutrition with nano-urea (0.4%) at active tillering along with PSAP (0.4%) at panicle initiation stage (T_5) resulted in more number of productive tillers per square metre (388 nos), which was comparable (378 nos) with foliar application of urea (2%) at AT followed by DAP at PI (T_7), and foliar application of nano-urea (0.4%) at AT along with KNO_3 (0.5%) at PI (T_6) (348 nos). Comparatively lesser number of productive tillers per square metre were observed in T_1 (0.4% nano-urea at AT + PI) (Table 4). Generally, the increase in the number of effective tillers is attributed to higher nitrogen application rates. Previous studies, such as those by Woyema *et al.* (2012) [41] and Lampayan *et al.* (2010) [21], also confirmed that nitrogen fertilization boosts tiller production. The number of effective tillers serves as a key indicator of yield potential, as it plays a crucial role in determining crop yield. Moro *et al.* (2015) [25] also observed a rise in tiller number with increased nitrogen levels. Additionally, Benzon *et al.* (2015) [6] reported that reproductive tillers were significantly influenced by the use of conventional fertilizers in combination with nanofertilizers. PSAP is reported to be 180 per cent water-soluble, enabling quick absorption through leaves, which is essential for enhancing the availability of phosphorus and potassium to plants. The synergistic effect of potassium and phosphorus in PSAP stimulates metabolic processes that are essential for the development of tillers (Nandargikar *et al.*, 2023) [26].

2.2 Grains per panicle

The treatment, T_5 (nano-urea and PSAP at 0.4% each during AT and PI stages respectively) recorded the highest number of grains per panicle (202.33 nos). This was followed by T_4 (190.33) which was comparable with T_3 (189.33) and T_7 (188.33). Comparatively, lower number of grains per panicle was noted in response to foliar nutrition of 0.4 per cent each of nano-urea at AT and PI stages respectively (T_1) (Table 4). This might be a result of increased enzymatic activity, which could have facilitated the formation and movement of photosynthates, thereby influencing the number of grains per panicle (Midde *et al.*, 2022; Sahu *et al.*, 2022) [24, 30]. Further, the effectiveness of spraying at the appropriate timing and location might have also contributed to a higher number of filled grains and a lesser number of empty grains, as explained by Jassim *et al.* (2019) [15]. Sharma *et al.* (2023) [31] noted that phosphorus (P) played a key role in supporting photosynthesis, promoting root growth and development, enhancing nutrient absorption, and storing energy as ATP, all of which contributed to improved yield attributes. Similar findings were reported by Nkaa *et al.* (2014) [28], Singh *et al.* (2015) [36], and Lal *et al.* (2016) [20]. Proper timing ensures that the plant has the necessary nutrients available when it is most needed for grain filling, thereby reducing the likelihood of sterility. Also, the combination of nitrogen and phosphorus is known to have synergistic effects on the growth and development of rice plants. Nitrogen enhances vegetative growth, while phosphorus supports root and reproductive development, leading to improved grain set and lower sterility (Zhang *et al.*, 2018) [43].

2.3 Grain yield

Foliar application of nano-urea (0.4%) at AT followed by PSAP (0.4%) at PI (T_5) noted to result higher grain yield of rice (5.44 t ha^{-1}). However, it was observed to be statistically comparable with T_7 (5.30 t ha^{-1}). The treatment T_8 (KAU POP) was observed to remain at par with T_6 and T_7. Grain yield was lower with 0.4 per cent each of nano-urea at AT and PI stages (T_1) (Table 5).
The timely availability of nitrogen in accordance with the crop demand is crucial for increasing rice yields (Oenema *et al.*, 2014) [29]. In the present study, application of nano-urea to the foliage during the active tillering stage likely met the nitrogen needs of the rice. Furthermore, the gradual and controlled release of nitrogen from nano-urea might have also contributed significantly in enhancing rice yields. When applied to the leaves, the nanofertilizer might have been absorbed through the stomata and efficiently transported via the phloem (Thomas *et al.*, 2022) [37]. The availability and absorption of macro and micronutrients contributed to the improved yield resulting from the combined application of nano-urea and traditional basal fertilizers (Chowdhury *et al.*, 2014) [8]. The improved nutrient uptake by the crop led to a higher yield, which was attributed to an increase in source and sink strength (Verma *et al.*, 2022) [38]. A strong positive correlation was observed between the number of filled grains and grain yield, indicating that improvements in yield parameters, such as filled grains, significantly contributed to the overall grain yield. Bhatt *et al.* (2023) [7] emphasized the effectiveness of PSAP in crops. The effectiveness of PSAP is associated with the active phosphorus in PSAP, which helps to generate additional energy molecules like phosphate bonds in adenosine diphosphate (ADP) and adenosine triphosphate (ATP).

2.4 Straw yield

Higher straw yield (7.39 t ha^{-1}), was recorded with urea (2%) at active tillering followed by DAP (2%) at panicle initiation (T_7) which was statistically at par with T_6 (7.30 t ha^{-1}) and KAU POP (6.93 t ha^{-1}). Foliar feeding of 0.4 per cent each of nano-DAP at active tillering and panicle initiation stages (T_2) resulted in lower straw yield (Table 5). This increase noted with foliar application of 2 per cent DAP (T_7) might be due to the significant increase in early vegetative growth, leading to increased straw yields.

These findings align with the research conducted by Ganapathy *et al*. (2008) [11] and Al-Khuzai and Al Juthery (2020) [3]. In another study conducted by Wang *et al*. (2021) [40], it was found that soil application of 75 per cent of the recommended dose (RD) of urea supplemented with foliar application significantly boosted straw yield by 15.67 per cent compared to 100 per cent RD as soil-applied urea. Similarly, Jamal *et al*. (2006) [14] observed that both foliar and soil applications of urea led to substantial increases in straw yield of wheat. Also, higher nitrogen doses were associated with increased straw yield, aligning with findings of Alam *et al*. (2015) [1].

Table 4: Effect of foliar nutrition on productive tillers per square metre and grains per panicle of rice, nos

Treatment	Productive tillers m^{-2}	Grains per panicle
T_1 – Nano Urea (0.4%) at AT and PI	222	157.33
T_2 – Nano DAP (0.4%) at AT and PI	298	172.33
T_3 – KNO_3 (0.5%) at AT and PI	286	189.33
T_4 – Nano Urea (0.4%) at AT + Nano DAP (0.4%) at PI	293	190.33
T_5 – Nano Urea (0.4%) at AT + PSAP (0.4%) at PI	388	202.33
T_6 – Nano Urea (0.4%) at AT + KNO_3 (0.5%) at PI	348	168.33
T_7 – Urea (2%) at AT + DAP (2%) at PI	378	188.33
T_8 – KAU POP	319	173.67
SEm(±)	22	3.11
CD (0.05)	66.8	9.437

AT- Active tillering; PI- Panicle initiation

Table 5: Effect of foliar nutrition on grain and straw yield of rice, t ha^{-1}

Treatment	Grain yield	Straw yield
T_1 – Nano Urea (0.4%) at AT and PI	4.25	5.78
T_2 – Nano DAP (0.4%) at AT and PI	4.34	5.72
T_3 – KNO_3 (0.5%) at AT and PI	4.38	6.17
T_4 – Nano Urea (0.4%) at AT + Nano DAP (0.4%) at PI	4.59	6.08
T_5 – Nano Urea (0.4%) at AT + PSAP (0.4%) at PI	5.44	6.68
T_6 – Nano Urea (0.4%) at AT + KNO_3 (0.5%) at PI	5.05	7.30
T_7 – Urea (2%) at AT + DAP (2%) at PI	5.30	7.39
T_8 – KAU POP	5.03	6.93
SEm(±)	0.10	0.21
CD (0.05)	0.302	0.649

AT- Active tillering; PI- Panicle initiation

Conclusion

From the present study, it could be concluded that reducing the recommended dose of nitrogen and phosphorus by 25 per cent and 50 per cent respectively along with 100 per cent recommended dose of potassium, supplemented with foliar application of nano-urea (0.4%) at active tillering stage followed by foliar application potassium salt of active phosphorus (0.4%) at panicle initiation stage was effective in enhancing the growth and yield of medium duration, transplanted rice.

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