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Studies on effect of foliar application of nano DAP and MAP on transplanted rice in Cauvery command area

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Abstract

A field experiment was carried out during *Kharif* 2024 and 2025 at 'I' Block, Zonal Agricultural Research Station, V. C. Farm, Mandya, Karnataka, to assess comparison between nano DAP, MAP and conventional fertilizers in transplanted rice. The experiment comprising of nine treatments which replicated three times using RCBD. The treatments included soil applications of phosphorus at 75 and 100 per cent along with foliar application of nano DAP and MAP at 0.4 and 2.0 percent during 45 days after transplanting. The soil application of 100 percent phosphorus along with foliar application of 0.4 percent nano DAP at 45 DAT (T_5) resulted in significantly higher grain (69.23 and 70.26 q ha⁻¹) and straw yield (87.32 and 88.23 q ha⁻¹) which was statistically on par with treatment which receiving soil application of 100 per cent phosphorus with foliar application of MAP at 2 percent during 45 DAT (T_9) recorded higher grain (67.28 and 69.75q ha⁻¹) and straw yield (87.02 and 88.14q ha⁻¹), during 2024 and 2025 respectively. However, higher total nutrients uptake viz., N (151.03kg ha⁻¹), P (49.83kg ha⁻¹), K (140.83kg ha⁻¹) was recorded in soil application of 100 percent phosphorus along with foliar application of 0.4 percent nano DAP at 45 DAT (T_5) compared to control. The study showed that application of 100 percent phosphorus along with foliar application of nano DAP or MAP showed good response than 75 percent phosphorus application along with foliar application of nano DAP or MAP at 45 days after planting.

Keywords: Yield, nutrient application, nutrient uptake, soil properties, cost economics

Introduction

Rice (*Oryza sativa* L.) is the staple food crop for more than half of the world's population and contributes nearly 20 per cent of the global dietary energy supply. In India, rice is cultivated on approximately 43.79 million hectares with a production of 135.76 million tonnes, making the country the second largest rice producer in the world after China (FAO, 2023) [4]. Sustaining high rice productivity requires adequate nutrient management, among which phosphorus (P) plays a crucial role as the second most important nutrient after nitrogen. Phosphorus is involved in several vital physiological and biochemical processes, including root development, tillering, flowering and energy transfer within the plant. Despite its importance, phosphorus use efficiency in Indian soils remains very low, generally ranging from 10 to 25 per cent. This low efficiency is primarily attributed to phosphorus fixation by clay minerals and iron (Fe) and aluminium (Al) oxides under acidic soil conditions and by calcium (Ca) compounds in alkaline soils (Meena *et al.*, 2019) [7].

In recent years, nano-fertilizers have emerged as a promising alternative for improving nutrient use efficiency in crop production. Owing to their extremely small particle size and large surface area, nano-fertilizers can enhance nutrient use efficiency by 18 to 30 per cent compared to conventional fertilizers. Their ability to release nutrients slowly and in a controlled manner minimizes nutrient losses through leaching and fixation, thereby ensuring greater nutrient availability to plants. Recent studies have further demonstrated that nano-formulations of phosphorus not only improve grain yield but also enhance grain quality and nutrient uptake efficiency in rice (Singh *et al.*, 2023) [11].

Apart from improving crop productivity, nano-diammonium phosphate (nano-DAP) offers significant economic and environmental advantages by reducing fertilizer losses and improving

nutrient utilization. Alongside nano-DAP, foliar application of conventional phosphorus fertilizers such as mono-ammonium phosphate (MAP) has been widely adopted because of its high solubility and rapid nutrient availability. Foliar applied MAP serves as an immediate source of phosphorus, particularly under conditions where soil phosphorus availability is limited due to fixation. However, despite the growing interest in nano-fertilizers, comparative studies evaluating nano-DAP and MAP under integrated soil and foliar phosphorus management strategies are limited, especially in transplanted rice ecosystems. Considering these aspects, the present study has been undertaken to identify suitable phosphorus management strategies for paddy cultivation in the Cauvery command area. By comparing the performance of nano-DAP and MAP under field conditions, the study aims to generate robust scientific evidence for optimizing phosphorus management in rice production while ensuring higher productivity, improved nutrient use efficiency and environmental sustainability. Keeping these considerations in view, the specific objectives of the study are: (i) to assess the effect of foliar application of nano-DAP and MAP on the growth, yield and nutrient uptake of paddy, and (ii) to evaluate the economics of paddy production under different phosphorus management practices.

Materials and Methods

A field experiment was conducted during the *Kharif* seasons of 2024 and 2025 at “I Block” of the Zonal Agricultural Research Station (ZARS), V.C. Farm, Mandya, Karnataka, to evaluate whether foliar application of nano-DAP could perform better than mono-ammonium phosphate (MAP) in transplanted rice. The experiment comprised nine treatment combinations involving 75 and 100 per cent phosphorus application levels along with foliar sprays of 0.4 per cent nano-DAP and 2 per cent MAP applied at 45 days after transplanting (DAT). The treatments were replicated three times and laid out in a Randomized Complete Block Design (RCBD). The rice variety KMP-220 was used for the study to assess the influence of different foliar phosphorus sources on the growth, yield and nutrient uptake of transplanted rice.

Prior to the initiation of the experiment, composite soil samples were collected from the experimental field at a depth of 0-15 cm and analyzed for their physical and chemical properties during 2024. The experimental soil was sandy loam in texture with an initial bulk density of 1.22 Mg m^{-3} . The soil reaction was acidic in nature with a pH of 6.21, while the electrical conductivity was 0.18 dS m^{-1} . The organic carbon content was medium (0.58%), and the cation exchange capacity (CEC) was $9.08 \text{ cmol (p}^+) \text{ kg}^{-1}$. The available nitrogen, phosphorus and potassium contents of the soil before the commencement of the experiment were 242, 48.21 and 311.3 kg ha^{-1} , respectively. The DTPA-extractable zinc content was 1.17 mg kg^{-1} .

The recommended dose of fertilizers (RDF) for rice under normal soil conditions, comprising 100 kg N , $50 \text{ kg P}_2\text{O}_5$ and $50 \text{ kg K}_2\text{O ha}^{-1}$, was supplied through straight fertilizers such as urea, single superphosphate (SSP) and muriate of potash (MOP), respectively. Nitrogen was applied through urea in three splits, with 50 per cent of the recommended dose applied as a basal application, 25 per cent at the tillering stage and the remaining 25 per cent at the panicle initiation stage. Phosphorus, in the form of SSP, and potassium, through MOP, were applied

entirely as a basal dose according to the treatment schedule. Observations on crop growth, yield and nutrient uptake were recorded at appropriate stages of crop growth. The collected data were subjected to statistical analysis using Fisher's method of analysis of variance (ANOVA). The significance of treatment effects was tested using the 'F' test at the 5 per cent probability level. Wherever the 'F' test indicated significant differences among treatments, the 't' test was employed to determine the critical difference (CD) and compare treatment means.

Results and Discussion

Growth Parameters

The data pertaining to growth parameters, namely plant height, number of tillers m^{-2} , number of panicles m^{-2} and SPAD meter readings, as influenced by different phosphorus management treatments during 2024 and 2025, are presented in Table 1. Among the various treatments, significantly higher growth parameters were recorded with the application of 100 per cent recommended dose of phosphorus (RDP) along with foliar application of nano-DAP at 0.4 per cent (T_5). The pooled mean data of two years revealed that T_5 recorded the highest plant height (93.00 cm), number of tillers (317.5 m^{-2}), number of panicles (234.5 m^{-2}) and SPAD meter reading (40.42). This treatment was found to be statistically superior to most of the other treatments and was closely followed by T_9 , which received 100 per cent RDP along with foliar application of MAP at 2.0 per cent. In contrast, the control treatment, which received only nitrogen and potassium without phosphorus application, recorded the lowest values for all growth parameters. The pooled mean plant height, number of tillers, number of panicles and SPAD meter reading under the control treatment were 72.76 cm, 276.5 m^{-2} , 196.5 m^{-2} , and 31.98, respectively.

The superior performance of the treatment receiving 100 per cent RDP combined with foliar application of nano-DAP may be attributed to enhanced phosphorus availability and uptake throughout the crop growth period. The nanoscale formulation of phosphorus possesses a larger surface area and greater solubility, which facilitates rapid absorption and efficient translocation within the plant system. This improved nutrient availability promotes root growth, enhances photosynthetic activity, and supports efficient assimilate partitioning, ultimately leading to increased tillering and panicle formation. Furthermore, foliar application of nano-DAP ensures targeted nutrient delivery during critical growth stages, thereby reducing nutrient losses and improving nutrient use efficiency.

Similarly, foliar application of MAP along with 100 per cent RDP also resulted in improved growth attributes compared to treatments receiving lower phosphorus levels, owing to its high water solubility and immediate availability of phosphorus to the crop. However, the comparatively better performance of nano-DAP indicates its greater efficiency in supplying phosphorus under field conditions. The present findings are in agreement with those reported by Meena *et al.*, who observed that nanoscale and water-soluble phosphorus formulations enhance nutrient absorption, photosynthetic efficiency, assimilate partitioning and tillering capacity in rice, resulting in improved vegetative growth and overall crop performance. Therefore, the integrated application of basal phosphorus along with foliar supplementation through nano-DAP proved to be an effective strategy for enhancing growth parameters in transplanted rice.

Table 1: Growth parameters of rice as influenced by foliar application of nano DAP and MAP in transplanted rice

Treatments	Plant height (cm) harvest			Tillers (Number /m ²)			Panicles (Number/m ²)			SPAD values @ 60DAT		
	2024	2025	Mean	2024	2025	Mean	2024	2025	Mean	2024	2025	Mean
T ₁	75.12	70.39	72.76	272	281	276.5	195	198	196.5	32.70	31.26	31.98
T ₂	80.72	82.31	81.52	285	292	288.5	210	204	207.0	34.02	35.26	34.64
T ₃	88.23	90.15	89.19	294	295	294.5	215	219	217.0	35.77	35.95	35.86
T ₄	89.25	88.32	88.79	308	312	310.0	221	223	222.0	36.93	37.12	37.03
T ₅	93.91	92.08	93.00	316	319	317.5	234	235	234.5	39.63	41.20	40.42
T ₆	88.76	89.32	89.04	301	304	302.5	218	220	219.0	35.50	36.25	35.88
T ₇	92.12	91.65	91.89	312	314	313.0	231	234	232.5	37.07	38.20	37.64
T ₈	89.12	88.99	89.06	302	311	306.5	220	224	222.0	37.75	37.12	37.44
T ₉	92.31	92.01	92.16	315	318	316.5	232	234	233.0	38.19	40.12	39.16
Sem ±	3.70	3.15		9.25	9.33		6.85	7.73		1.10	1.03	
CD (p≤0.05)	11.08	9.86		24.9	25.11		21.35	22.66		3.23	2.99	

Treatments details

T₁: Control (No P)T₂: 75% RDPT₃: 100% RDPT₄: 75% RDP + foliar application of nano DAP @ 0.4%T₅: 100% RDP + foliar application of nano DAP @ 0.4%T₆: 75% RDP + foliar application of MAP equivalent to nano DAP @ 0.4%T₇: 100% RDP + foliar application of MAP equivalent to nano DAP @ 0.4%T₈: 75% RDP + foliar application of MAP @ 2%T₉: 100% RDP + foliar application of MAP @ 2%

Yield Parameters

The data pertaining to yield parameters, namely dry matter accumulation, chaffiness, grain yield and straw yield of transplanted rice as influenced by different phosphorus management practices during 2024 and 2025, are presented in Table 2.

Significant differences among treatments were observed with respect to all yield parameters. During both years of experimentation, the treatment receiving 100 per cent recommended dose of phosphorus (RDP) along with foliar application of nano-DAP at 0.4 per cent (T₅) recorded the highest dry matter accumulation, grain yield and straw yield, along with the lowest chaffiness. During 2024 and 2025, T₅ recorded dry matter accumulation of 52.78 and 51.36 g hill⁻¹, grain yield of 69.23 and 70.26 q ha⁻¹, and straw yield of 87.32 and 88.23 q ha⁻¹, respectively. The same treatment also recorded the lowest chaffiness of 15.12 and 17.25 per cent during 2024 and 2025, respectively. This treatment was followed by T₉, which received 100 per cent RDP along with foliar application of MAP at 2.0 per cent.

In contrast, the control treatment receiving only nitrogen and potassium without phosphorus application recorded the poorest performance. It produced the lowest dry matter accumulation of 44.57 and 45.23 g hill⁻¹, grain yield of 52.69 and 53.21 q ha⁻¹, and straw yield of 65.23 and 65.98 q ha⁻¹ during 2024 and 2025,

respectively. The same treatment also recorded the highest chaffiness values of 25.67 and 23.31 per cent during the corresponding years. The reduction in chaffiness observed under nano-DAP foliar treatments can be attributed to improved spikelet fertility, efficient translocation of phosphorus to developing grains, and reduced reproductive sterility resulting from adequate phosphorus nutrition. Enhanced phosphorus availability during the reproductive stage promotes better grain setting and grain filling, thereby reducing the proportion of unfilled grains (Meena *et al.*, 2023) [6].

The superior grain and straw yields recorded with foliar application of nano-DAP may be attributed to enhanced nutrient use efficiency, improved root development, greater phosphorus uptake, and better grain filling efficiency. The nanoscale formulation facilitates rapid absorption and sustained nutrient availability, resulting in improved physiological activity and higher productivity (Raliya and Tarafdar, 2013; Meena *et al.*, 2023) [10, 6]. Furthermore, the higher dry matter accumulation observed in phosphorus-applied treatments indicates increased vegetative growth, greater biomass production, and efficient utilization of photosynthates, which ultimately contributed to enhance grain and straw yields. Similar findings have been reported by Dwivedi *et al.* (2021) [3], who observed improved biomass accumulation and yield in rice under adequate phosphorus nutrition

Table 2: Yield parameters and yield of rice as influenced by foliar application of nano DAP and MAP in transplanted rice

Treatments	Dry matter accumulation (g hill ⁻¹)			Chaffiness (%)			Grain Yield (q ha ⁻¹)			Straw Yield (q ha ⁻¹)		
	2024	2025	Mean	2024	2025	Mean	2024	2025	Mean	2024	2025	Mean
T ₁	44.57	45.23	44.90	25.67	23.31	24.49	52.69	53.21	52.95	65.23	65.98	65.61
T ₂	48.54	47.26	47.90	19.89	20.13	20.01	59.44	59.23	59.34	73.28	72.36	72.82
T ₃	50.84	51.23	51.04	17.52	18.23	17.88	61.73	62.68	62.21	78.26	73.12	75.69
T ₄	53.26	52.31	52.89	16.11	18.10	17.11	63.12	65.35	64.24	80.14	81.23	80.69
T ₅	56.23	54.63	55.43	15.12	17.25	16.19	69.23	70.26	69.75	87.32	88.23	87.78
T ₆	52.78	51.36	52.07	16.19	18.26	17.23	62.12	63.25	62.69	79.23	79.38	79.31
T ₇	55.55	53.26	54.41	15.92	17.65	16.79	66.14	68.12	67.13	86.23	85.68	85.96
T ₈	52.13	52.36	52.25	16.24	18.69	17.47	63.19	63.98	63.59	82.13	81.68	81.91
T ₉	55.32	54.21	54.77	15.99	17.39	16.69	67.28	69.75	68.52	87.02	88.14	87.58
SEm±	2.20	2.31		0.88	0.95		5.11	6.01		5.35	5.65	
CD (P≤0.05)	6.59	6.91		2.63	2.81		15.31	15.05		15.94	16.25	

Treatments details
T₁: Control (No P)
T₂: 75% RDP
T₃: 100% RDP
T₄: 75% RDP + foliar application of nano DAP @ 0.4%
T₅: 100% RDP + foliar application of nano DAP @ 0.4%
T₆: 75% RDP + foliar application of MAP equivalent to nano DAP @ 0.4%
T₇: 100% RDP + foliar application of MAP equivalent to nano DAP @ 0.4%
T₈: 75% RDP + foliar application of MAP @ 2%
T₉: 100% RDP + foliar application of MAP @ 2%

Effect of Different Phosphorus Management Practices on Root Growth of Paddy

Root growth parameters, namely root volume, root length, root fresh weight, and root dry weight of transplanted rice, were significantly influenced by different phosphorus management practices, and the results are presented in Table 3. Among the treatments, the application of 100 per cent RDP along with foliar spray of nano-DAP at 0.4 per cent (T₅) recorded significantly superior root growth parameters during both years of study. At harvest, T₅ recorded the highest root volume of 47.68 and 48.35 cm³, root length of 19.73 and 19.71 cm hill⁻¹, root fresh weight of 11.59 and 11.62 g hill⁻¹, and root dry weight of 6.54 and 6.59 g hill⁻¹ during 2024 and 2025, respectively. This treatment was closely followed by T₉, which received 100 per cent RDP along with foliar application of MAP at 2.0 per cent. The control treatment, where phosphorus was omitted, recorded the lowest values for all root growth parameters. Root volume was 37.26 and 39.25 cm³, root length was 13.81 and 13.99 cm hill⁻¹, root fresh weight was 7.65 and 8.12 g hill⁻¹, and root dry weight was 3.55 and 3.85 g hill⁻¹ during 2024 and 2025, respectively. The marked improvement in root growth under nano-DAP treatments can be attributed to the critical role of phosphorus in

stimulating root initiation, elongation, and branching. Adequate phosphorus availability enhances cell division and energy transfer processes, resulting in vigorous root development and greater root biomass. The foliar application of nano-DAP, in combination with basal phosphorus application, likely improved phosphorus availability throughout the crop growth period, leading to enhanced root proliferation and nutrient acquisition. Improved root architecture subsequently facilitated greater uptake of water and nutrients, which contributed to better crop growth and yield performance. The results indicate that integrated phosphorus management involving basal phosphorus application along with foliar supplementation through nano-DAP was highly effective in improving root growth characteristics, thereby enhancing the overall productivity of transplanted rice. The improvement in root studies observed in nano DAP or MAP foliar spray may be attributed to enhanced phosphorus efficiency which improves ATP production, root vigor and efficient utilization of carbon skeletons for root growth (Rai *et al.*, 2012; Meena *et al.*, 2023) ^[9, 6] and enhanced phosphorus availability in the rhizosphere, which promoted root initiation, elongation and proliferation, thereby enabling efficient absorption of water and nutrients (Kumar *et al.*, 2021; Meena *et al.*, 2023) ^[5, 6].

Table 3: Effect of foliar application of nano DAP and MAP on root studies of transplanted rice

Treatments	Root volume (cm ³)		Root Length (cm hill ⁻¹)		Root Fresh Weight (g hill ⁻¹)		Root Dry Weight (g hill ⁻¹)	
	2024	2025	2024	2025	2024	2025	2024	2025
T ₁	37.26	39.25	13.81	13.99	7.65	8.12	3.55	3.85
T ₂	40.35	41.23	14.82	15.23	8.11	8.36	4.15	4.21
T ₃	41.25	42.35	15.56	15.98	8.77	8.96	4.53	4.61
T ₄	45.47	44.98	17.77	16.98	10.45	10.51	5.42	5.51
T ₅	47.68	48.35	19.73	19.71	11.59	11.62	6.54	6.59
T ₆	44.95	43.68	17.45	17.51	10.19	10.17	5.12	5.1
T ₇	46.87	46.25	19.36	19.12	11.23	11.42	6.08	6.05
T ₈	44.43	46.23	16.87	16.23	9.65	9.85	4.76	5.01
T ₉	46.43	47.94	18.97	19.65	10.89	11.54	5.99	6.34
SE m±	1.84	1.68	0.71	0.8	0.4	0.42	0.2	0.21
CD @ 5 per cent	5.53	5.23	2.13	2.36	1.21	1.31	0.62	0.66

Effect of foliar application of nano DAP and MAP on primary nutrient uptake in grain and straw at harvest in transplanted rice

Pooled analysis of two years data (2024 & 2025) revealed that, the maximum total nitrogen, phosphorus and potassium uptake was recorded in application of 100% phosphorus fertilizers along with foliar application of phosphorus sources than application of 75% phosphorus contains fertilizers (Table. 4). Among the treatments higher total N (151.03 kg ha⁻¹) P (49.83 kg ha⁻¹) and K (140.83 kg ha⁻¹) were observed in T₅: 100 per cent RDP + Foliar application of Nano DAP @ 0.4 per cent respectively, followed by T₉: 100 per cent RDP + FA of MAP @ 2 per cent (147.94,47.53, 138.78kg NPK ha⁻¹ respectively) and the lowest NPK uptake (97.35, 23.48 &84.53 kg ha⁻¹ respectively) was recorded observed incontrol (without

application of P),due to nutrient deficiency limiting dry matter accumulation. The superior performance of T₅ is due to enhanced nutrients assimilation and translocation to grain through efficient leaf penetration and higher nutrient-use efficiency of Nano DAP particles (Prasad *et al.*, 2012; Meena *et al.*, 2023) ^[8, 6] and better root growth and improved P–K interaction in the rhizosphere, as adequate phosphorus enhances potassium transport and partitioning in plants (Dobermann & Fairhurst, 2000) ^[2]. **Effect of foliar application of nano DAP and MAP on micro nutrient uptake in grain and straw at harvest in transplanted rice** Pooled analysis of two years data (2024 & 2025) revealed that, the maximum total iron, manganese, copper and zinc (1963.29,

1408.54, 286.19 and 481.89 g ha⁻¹ respectively) were recorded in the treatment which received 100 per cent RDP + foliar application of nano DAP @ 0.4 per cent respectively, followed by T₉ which received 100 per cent RDP + FA of MAP @ 2 per cent (1911.93, 948.87, 187.86 and 480.31 Fe, Mn, Cu and Zn g ha⁻¹ respectively) and the lowest total micronutrients uptake (1426.83, 1408.54, 286.19 and 360.48 g ha⁻¹ respectively) was recorded observed in control (without application of P)

(Table.5). The superior. performance of Nano DAP is explained by its Nano-size enhancing leaf absorption and micronutrients mobility, which plays a vital role in photosynthesis and enzymatic activities (Meena *et al.*, 2023) ^[6] and also more zinc availability is could be due to the positive interaction of phosphorus with zinc observed in balanced fertilization, while Foliar sprays minimized P-induced Zn deficiency by providing immediate availability (Subba Rao *et al.*, 2019) ^[12].

Table 4: Effect of foliar application of nano DAP and MAP on total primary nutrient uptake in grain and straw of transplanted rice

Treatments	N (kg ha ⁻¹)			P (kg ha ⁻¹)			K (kg ha ⁻¹)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T ₁ : Control (No P)	56.91	40.44	97.35	13.70	9.78	23.48	25.82	58.71	84.53
T ₂ : 75 per cent RDP	66.57	48.36	114.94	17.83	14.66	32.49	32.69	71.81	104.51
T ₃ : 100 per cent RDP	70.99	54.76	125.75	19.14	17.99	37.13	35.80	79.01	114.82
T ₄ : 75 per cent RDP + FA of Nano DAP@0.4 per cent	73.85	57.69	131.54	22.09	19.23	41.32	38.50	84.13	122.63
T ₅ : 100 per cent RDP + FA of Nano DAP @0.4 per cent	83.08	67.95	151.03	26.31	23.52	49.83	45.00	95.83	140.83
T ₆ : 75 per cent RDP + FA of MAP equivalent to Nano DAP@ 0.4 per cent	72.06	55.39	127.45	19.88	18.20	38.08	38.51	84.67	123.18
T ₇ : 100 per cent RDP + FA of MAP equivalent to Nano DAP@ 0.4 per cent	78.71	66.40	145.10	23.81	22.42	46.23	42.33	94.85	137.18
T ₈ : 75 per cent RDP + FA of MAP @ 2 per cent	72.67	58.31	130.98	19.59	19.71	39.30	37.91	88.70	126.61
T ₉ : 100 per cent RDP + FA of MAP @ 2 per cent	80.06	67.88	147.94	24.89	22.63	47.52	43.06	95.72	138.78
SE m±	3.08	2.40	5.48	0.85	0.76	1.61	1.56	3.50	5.07
CD @ 5 per cent	9.25	7.19	16.43	2.56	2.26	4.82	4.69	10.50	15.19

Table 5: Effect of foliar application of nano DAP and MAP on total uptake of micro nutrients in grain and straw of transplant rice

Treatments	Fe (g ha ⁻¹)			Mn (g ha ⁻¹)			Cu (g ha ⁻¹)			Zn (g ha ⁻¹)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T ₁ : Control (No P)	355.24	1071.60	1426.83	321.88	626.99	948.87	10.96	176.90	187.86	107.65	252.83	360.48
T ₂ : 75 per cent RDP	425.89	1259.83	1685.72	369.54	699.24	1068.78	17.48	197.71	215.18	123.40	298.18	421.57
T ₃ : 100 per cent RDP	431.31	1303.70	1735.01	390.87	756.09	1146.97	20.49	211.38	231.87	120.62	309.63	430.25
T ₄ : 75 per cent RDP + FA of Nano DAP@0.4 per cent	497.76	1371.89	1869.66	415.08	816.58	1231.66	21.78	218.17	239.94	142.52	322.32	464.85
T ₅ : 100 per cent RDP + FA of Nano DAP @0.4 per cent	500.81	1462.48	1963.29	493.96	914.59	1408.54	33.72	252.47	286.19	142.96	335.93	481.89
T ₆ : 75 per cent RDP + FA of MAP equivalent to Nano DAP@ 0.4 per cent	485.34	1366.34	1851.68	425.77	746.35	1172.12	22.67	213.73	236.40	133.12	327.99	461.12
T ₇ : 100 per cent RDP + FA of MAP equivalent to Nano DAP@ 0.4 per cent	483.62	1443.75	1927.36	477.07	881.36	1358.42	27.98	245.93	273.91	126.72	336.04	462.76
T ₈ : 75 per cent RDP + FA of MAP @ 2 per cent	489.98	1397.11	1887.09	424.19	799.45	1223.65	20.92	223.39	244.31	143.13	328.60	471.73
T ₉ : 100 per cent RDP + FA of MAP @ 2 per cent	487.24	1424.69	1911.93	495.52	904.75	1400.26	28.32	244.44	272.76	136.71	344.60	480.31
SE m±	19.13	57.95	77.08	17.90	33.66	51.6	0.90	9.41	10.3	5.45	13.27	18.71
CD @ 5 per cent	57.36	173.75	231.11	53.68	100.90	154.6	2.71	28.22	30.9	16.33	39.78	56.11

Soil electro-chemical properties Content after the harvest of rice influenced by effect of foliar application of nano DAP and MAP on transplanted rice

Chemical properties

The changes in physical and chemical properties of soil after the harvest of rice crop due to soil and Foliar application of phosphorous or presented in Table 6.

Application of phosphorus through fertilizers along with foliar application of nano DAP and MAP showed non-significant difference in soil pH and other major and micro soil nutrient except EC and available phosphorus content in soil. Among the treatments highest available soil nutrient status was noticed in application of 100% phosphorus compared to application of 75% phosphorus to soil. The highest phosphorus (44.21 kg ha⁻¹) was recorded in the application of 100% phosphorus along with foliar application of 0.4% of nano DAP and less available phosphorus (33.20 kg ha⁻¹) was recorded in the control (without P). The significant buildup of soil P in Foliar + basal P application treatments may be due to improved P recovery efficiency and reduced soil fixation, since foliar applied phosphorus bypasses soil P immobilization (Subba Rao *et al.*, 2019; Chen *et al.*, 2021) ^[12, 1].

Economics of rice production as influenced by foliar application of phosphorus fertilizers like Nano-DAP and MAP on transplanted rice

The economic analysis clearly demonstrates that foliar application of phosphorus fertilizers (Nano-DAP and MAP) in combination with soil-applied phosphorus substantially improved returns compared to sole soil application or control (Table 7). Among the treatments pooled data of 2024 and 2025 revealed that, highest gross return (194567 ₹ ha⁻¹), net return (113221 ₹ ha⁻¹) and B:C (1.39) ratio was noticed in the treatment which received 100% phosphorus along with foliar application of 0.4% of nano DAP compared to control (147706 ₹ ha⁻¹ 71190 ₹ ha⁻¹ and 0.93 of gross return, net return and B:C ratio respectively). Overall, the data clearly establish that 100 per cent RDP combined with Foliar Nano DAP (T₅) was the most profitable option, followed closely by MAP-based treatments (T₇ and T₉). Thus, Foliar supplementation of phosphorus not only improves crop productivity but also enhances economic returns, making it a viable strategy for optimizing phosphorus use efficiency in rice cultivation.

Table 6: Soil electro chemical properties after the harvest of rice influenced by effect of foliar application of nano DAP and MAP on transplanted rice (Pooled data of 2024 and 2025)

Treatments	pH (1:2.5)	EC (dS m ⁻¹)	OC (%)	Avail. N (kg ha ⁻¹)	Avail. P ₂ O ₅ (kg ha ⁻¹)	Avail. K ₂ O (kg ha ⁻¹)	DTPA-Fe (mg/kg)	DTPA-Mn (mg/kg)	DTPA-Cu (mg/kg)	DTPA-Zn (mg/kg)
T ₁	6.09	0.16	0.59	200.32	33.20	80.16	21.63	4.94	2.95	2.08
T ₂	6.13	0.21	0.55	224.21	40.41	81.09	23.18	4.89	2.91	2.02
T ₃	6.18	0.19	0.56	232.57	43.17	80.58	22.18	4.92	2.92	2.05
T ₄	6.23	0.15	0.54	230.80	43.22	79.03	24.16	4.91	2.89	1.93
T ₅	6.14	0.17	0.57	231.41	44.21	80.91	22.64	4.88	2.95	1.95
T ₆	6.26	0.14	0.60	229.33	40.33	78.48	24.76	4.93	2.92	1.92
T ₇	6.12	0.16	0.55	234.78	43.25	81.04	22.13	4.94	2.93	1.96
T ₈	6.28	0.17	0.59	214.68	41.32	79.54	24.68	4.91	2.94	1.94
T ₉	6.21	0.16	0.54	220.27	42.12	72.38	23.64	4.90	2.9	1.92
SE m±	0.28	0.01	0.03	9.56	1.72	3.33	0.87	0.13	1.08	1.04
CD @ 5 per cent	NS	0.02	NS	NS	5.16	NS	NS	NS	NS	NS

Table 7: Economics of rice production as influenced by foliar application of phosphorus fertilizers like nano-DAP and MAP on transplanted rice (Pooled data of 2024 and 2025)

Treatments	Cost of cultivation (₹ ha ⁻¹)	Gross returns (₹ ha ⁻¹)	Net returns (₹ ha ⁻¹)	B:C ratio
T ₁ : Control (No P)	76516	147706	71190	0.93
T ₂ : 75 per cent RDP	79325	166521	87197	1.10
T ₃ : 100 per cent RDP	80266	173681	93415	1.16
T ₄ : 75 per cent RDP + FA of Nano DAP@0.4 per cent	80404	177636	97232	1.21
T ₅ : 100 per cent RDP + FA of Nano DAP @0.4 per cent	81346	194567	113221	1.39
T ₆ : 75 per cent RDP + FA of MAP equivalent to Nano DAP@ 0.4 per cent	79424	174920	95496	1.20
T ₇ : 100 per cent RDP + FA of MAP equivalent to Nano DAP@ 0.4 per cent	80366	186932	106566	1.33
T ₈ : 75 per cent RDP + FA of MAP @ 2 per cent	81324	178506	97182	1.19
T ₉ : 100 per cent RDP + FA of MAP @ 2 per cent	82266	189911	107645	1.31

References

- Chen Q, Ma D, Xie R, Zhu H, Zang S. Study on a fast EC measurement method of soda saline-alkali soil based on wavelet decomposition texture feature. *Catena*. 2021;203:105272.
- Dobermann A, Fairhurst T. Rice in the global food supply. *World*. 2000;(7502):349-454.
- Dwivedi BS, Bhattacharyya R, Kumar R, Bandyopadhyay KK, Saha M, Chawla G, *et al.* Preparation of novel biodegradable starch/poly(vinyl alcohol)/bentonite grafted polymeric films for fertilizer encapsulation. *Carbohydr Polym*. 2021;259:117679.
- Food and Agriculture Organization of the United Nations. World food and agriculture: Statistical yearbook 2023. Rome: Food and Agriculture Organization of the United Nations; 2023.
- Kumar R, Ram H, Meena RK, Kumar M, Verma AK, Kumar S, *et al.* Effect of nano nitrogen application on yield, nutrient uptake and profitability in fodder oat (*Avena sativa* L.) observed in north western Haryana condition. *Range Manag Agrofor*. 2021;43(2):340-344.
- Meena RH, Jat G, Jain D. Impact of foliar application of different nano-fertilizers on soil microbial properties and yield of wheat. *J Environ Biol*. 2023;42(2):302-308.
- Meena SN, Yadav BD, Yadav RK, Nogiya M, Yadav MR, Yadav AK, *et al.* Phosphorus management strategies to enhance P-use efficiency and sustainable crop production. *Int J Chem Stud*. 2019;9(1):421-428.
- Prasad TNVKV, Sudhakar P, Sreenivasulu Y, Latha P, Munaswamy V, Reddy KR, *et al.* Effect of nanoscale zinc oxide particles on the germination, growth and yield of peanut. *J Plant Nutr*. 2012;35(6):905-927.
- Rai V, Acharaya S, Dey N. Implications of nanobiosensors in agriculture. *J Biomater Nanobiotechnol*. 2012;3:315-324.
- Raliya R, Tarafdar JC. ZnO nanoparticle biosynthesis and its effect on phosphorus-mobilizing enzyme secretion and gum contents in cluster bean (*Cyamopsis tetragonoloba* L.). *Agric Res*. 2013;2(1):48-57.
- Singh YK, Ram N, Tiwari VK, Katiyar D. Performance of wheat (*Triticum aestivum* L.) influenced by the application of nano-fertilizers. *Int J Plant Soil Sci*. 2023;35(13):262-270.
- Subba Rao N, Srihari C, Deepthi Spandana B, Sravanthi M, Kamalesh T, Abraham Jayadeep V. Comprehensive understanding of groundwater quality and hydrogeochemistry for the sustainable development of suburban area of Visakhapatnam, Andhra Pradesh, India. *Hum Ecol Risk Assess Int J*. 2019;25(1-2):52-80.