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Effect of nano DAP fertilizer on growth and yield of rice (*Oryza sativa* L.)

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Abstract
A field experiment was conducted during *kharif* season of 2021 at instructional farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur (Chhattisgarh) to assess the "Effect of Nano DAP fertilizer on Growth and Yield of Rice (*Oryza sativa* L.)". The experiment was laid out in Randomized Block Design with seven treatments and three replications. The results revealed that all the growth parameters and yield attributes were significantly influenced by different treatments. Application of 75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two foliar spray of Nano DAP at 25 and 50 DAT significantly increased the growth parameters, yield attributes and yield of rice *viz*., grain yield (54.78 q ha^{-1}) and straw yield (57.33 q ha^{-1}). In terms of economics of rice cultivation, application of 75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two spray of Nano DAP at 25 and 50 DAT (T_7) obtained higher gross income (Rs. 1,48,416 ha^{-1}), net income (Rs. 94,204 ha^{-1}) and benefit : cost ratio (1.74) due to basal application of conventional DAP fertilizer and in later growth stages of crop two foliar application of nano DAP fertilizer increase the nutrient use efficiency as well as yield of rice as compare to other treatments.

Keywords: IFFCO nano DAP fertilizer, transplanted rice, growth and yield, economics of rice

Introduction
Rice is one of the leading food crop of the world and essential part of national economy. Rice is one of the most important staple food consumed in Asian countries. Rice is most important food crop of India in terms of area, production and consumer preference. Chhattisgarh is known as 'Rice Bowl' of central India. Chhattisgarh, a newly formed state in eastern India, is relatively under developed in terms of agricultural productivity when compared to the majority of Indian states (Netam and Sahu, 2017) [20].

The rice crop mostly depends on the soil conditions for its growth, development and grain yield. Plants require a specific amount of some nutrients in a specific form for their growth and development (Rathnayaka *et al*., 2018, Elavarasan *et al*., 2021) [26, 36]. To increase agricultural production, the use of fertilizers in the soil is the common practice to increase the yield to fulfil the ever increasing demands of modern populations (Chhipa, 2017) [4]. Nevertheless, common fertilizers do not provide promising results because most of the conventional fertilizers get wasted and do not reach the target area due to the losses by volatilization, drift, hydrolysis, leaching, runoff and microbial or photolytic degradation of nutrients (Manjunatha *et al*., 2019) [17]. On the other side, large quantities of fertilizers become the reason to increase the water pollution.

The farmers are using a large quantities of fertilizers to increase the yield and production. On one side, the conventional fertilizers are increasing crop production, but on the other side, the nutrient supply of these fertilizers seemed to be very low because 50-70% of their nutrients are lost into the environment and are not used by the plants (Marchiol, 2019) [18]. Consequently, the fertilizers applied for higher crop production, pollute the environment and show poor economic efficiency (Nguyen *et al*., 2019) [7].

Nanotechnology has great potential as it has enormous applications in the agricultural and environmental fields due to its unique chemical and electronic characteristics (Qureshi *et al*., 2018, Chhipa, 2019) [25, 5]. Nanotechnology converts crystallites to nano-sized particles, increasing their surface area and providing them with significant transduction properties, leading to sustainable agriculture production (León-Silva *et al*., 2018, Kopittke *et al*., 2019) [13, 12]. Nano-fertilizers are the substances consisting of nano-particles and use nanotechnology for the improvement of nutrient use efficiency. Potentials of nano-fertilizers include specific release, control release, moisture release and quick diffusion (Mikkelsen, 2018) [19].

Nano-fertilizer have large surface area and less particle size than the pore size of root and leaves of the plant which can increase penetration into the plant from applied surface and improve uptake and nutrient use efficiency of the nano-fertilizer. Reduction of particle size results in increased specific surface area and number of particles per unit area of a fertilizer that provide more opportunity to contact of nano-fertilizers which leads to more penetration and uptake of the nutrient (Lin and Xing, 2007) [14].

In plants, P is an essential element required for development and reproduction, and it is one of the main components of the fertilizers necessary to sustain modern agriculture. In soils, the concentration of inorganic P (available to plants) ranges from 35 to 70% of the total P. This form of P shows low diffusion and high fixation rates in soils through ligand exchange by 1: 1 clay minerals, Fe and Al oxides and hydroxides, and is thus precipitated as Fe, Al, and Ca phosphates (Shen *et al*., 2011, Almeida *et al*., 2018) [30, 1]. Additionally, phosphate fertilizers are obtained from phosphoric rock, a non-renewable resource, and whose reserves are running out (Schröder *et al*., 2009) [29]. Consequently, the importance of promoting the efficiency of P uptake and use in agricultural crops like rice becomes evident, while supplying nano-fertilizers with phosphorus represents an alternative.

Nitrogen is one of the important elements in plants because of its key part in chlorophyll formation, which is basic for the photosynthesis process. Managing rice crop's nitrogen nutrition is difficult because lowland rice crop culture leads to nitrogen losses through ammonia volatilization, nitrification, denitrification, leaching and runoff (Johnson, 2006) [9], which decreases the availability of nitrogen for rice plants. Fertilizers encapsulated in nano-particles will increase availability and uptake of nutrient to the crop plants (Liscano *et al*., 2000) [15]. Nano-fertilizers are capable to release nutrient slowly to the crop plant which increase availability of nutrient to the crop throughout the growth period which prevent loss of nutrient from denitrification, volatilization, leaching and fixation in the soil especially NO_3^- N and NH_4^+ N.

However, studies need to be carried out on crops like rice to know the nutrient use efficiency by using nano-fertilizers. Imbalanced and excess uses of conventional fertilizers discouraged, need to reduce the input cost and also to enhance the nutrient use efficiency through proper methods of application. Hence, the present study was conducted to assess the growth, yield attributes and yield increase of rice crop by the application of Nano DAP fertilizer.

Materials and Methods

A field experiment was conducted during *kharif* season of 2021 at instructional farm, Barrister Thakur Chhedilal College of Agriculture and Research Station, Bilaspur (Chhattisgarh) to investigate the "Effect of Nano DAP fertilizer on Growth and Yield of Rice (*Oryza sativa* L.)". The experimental field was geographically situated in the central part of Chhattisgarh state at latitude 22.0796° N, longitude 82.1391° E and altitude of 262.0 meters above the MSL. The geographical region comes under the Eastern Plateau and Hills region (Agro-climatic zone - 07) of India. Chhattisgarh has three Agro-climatic zones, in which Bilaspur comes under the Chhattisgarh plain zone. The experiment farm is characterized by a hot, moist and sub-humid region, receives an average of 1250 mm annual rainfall every year. The soil condition of experimental field was neutral in pH (6.8), electrical conductivity 0.25 dSm^{-1}, bulk density 1.32 g cc^{-1} and particle density 2.62 g cc^{-1}, clay loam in texture, low in available N (218.5 kg ha^{-1}), medium in available P_2O_5 (13.88 kg ha^{-1}) and available K_2O (275.96 kg ha^{-1}).

Zinco rice (MS) variety of rice was selected for the experimental crop with spacing of row to row 20 cm and plant to plant 15 cm in distance. The experiment was laid out in Randomized Block Design (RBD) with three replications and 7 treatment combinations and experimental plots were laid out with dimensions as gross plot area (5 m × 4.50 m) and net plot area (4.60 m × 4.20 m). The treatments *viz.*, T_1 – 100% RDF as basal, T_2 – 25% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + one foliar spray of Nano DAP at 25 DAT, T_3 - 25% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two foliar spray of Nano DAP at 25 and 50 DAT, T_4 - 50% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + one foliar spray of Nano DAP at 25 DAT, T_5 - 50% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two foliar spray of Nano DAP at 25 and 50 DAT, T_6 - 75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + one foliar spray of Nano DAP at 25 DAT, T_7 - 75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two foliar spray of Nano DAP at 25 and 50 DAT.

The recommended dose of nutrients 100:60:40 N, P_2O_5, K_2O kg ha^{-1} was applied through DAP, Urea and MOP for the experiment under transplanted rice condition. The recommended dose of K_2O was common for all the treatments. The appropriate amount of conventional fertilizers can be calculated and applied as per the treatment schedule. Root dipping of rice seedlings in 0.5% solution of Nano DAP fertilizer for 15-20 minutes before transplanting. Foliar application of Nano DAP fertilizer @ 2 ml $litre^{-1}$ of water @ 500 litres of water ha^{-1}. The data obtained for the parameters under study were tabulated an analyzed by the method of analysis of variance as described by Panse and Sukhatme (1967) [22].

Results and Discussion

Growth and yield attributes

The growth and yield components *viz.*, plant height (cm), number of tillers m^{-2}, dry matter accumulation (g) $plant^{-1}$, root biomass production (g) $plant^{-1}$, LAI (presented in Table 1) in various stages of rice growth and number of effective tillers m^{-2}, panicle length (cm), total number of grains $panicle^{-1}$ and filled grains $panicle^{-1}$ (presented in Table 2) was enhanced due to combined application of conventional and Nano DAP fertilizer. At 25 DAT, the higher growth parameters were observed under the treatment T_1 (100% RDF as basal) *viz.*, plant height of 60 cm, number of tillers 156.67 m^{-2}, dry matter accumulation 9.82 g $plant^{-1}$, root biomass production 4.09 g $plant^{-1}$, LAI 1.72 due to application of 100% RDF of conventional fertilizer as basal. At 50 DAT, 75 DAT and at harvest stage the higher growth parameters were recorded *viz.*, plant height of 89.67, 117.58 and 130.27 cm, number of tillers 184.60, 211.87 and 206.53 m^{-2}, dry matter accumulation 21.54, 81.23 and 120.73 g $plant^{-1}$, root biomass production 12.33, 25.45 and 23.18 g $plant^{-1}$, LAI 3.85, 4.56 and 4.41, respectively under the treatment T_7 (75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two foliar spray of Nano DAP at 25 and 50 DAT).

Table 1: Effect of Nano DAP fertilizer on growth parameters of rice

Treatment details		Plant height (cm)	Number of tillers m^{-2}	DMA (g) $plant^{-1}$	RBP (g) $plant^{-1}$	LAI
T_1	100% RDF as basal	124.17	199.03	109.06	21.45	4.25
T_2	25% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + one spray of Nano DAP at 25 DAT	87.20	157.27	68.61	10.23	3.31
T_3	25% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two spray of Nano DAP at 25 and 50 DAT	92.87	164.43	72.10	12.07	3.52
T_4	50% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + one spray of Nano DAP at 25 DAT	110.16	184.27	90.72	15.52	3.83
T_5	50% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two spray of Nano DAP at 25 and 50 DAT	114.07	189.40	96.55	18.04	4.01
T_6	75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + one spray of Nano DAP at 25 DAT	126.20	203.80	114.41	22.44	4.40
T_7	75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two spray of Nano DAP at 25 and 50 DAT	130.27	211.87	120.73	25.45	4.56
SEm (±)		4.09	5.10	4.18	1.52	-
CD (5%)		12.60	15.73	12.89	4.68	-

DMA = Dry matter accumulation, RBP = Root biomass production, LAI = Leaf area index

Besides, the yield attributes like higher number of effective tillers 194.20 m^{-2}, panicle length 24.90 cm, total number of grains 155.83 $panicle^{-1}$ and filled grains 147 $panicle^{-1}$ at harvest, during the crop period. This fact indicates that the combined application of nano DAP and conventional fertilizers encourages the plant to absorb and utilize the nutrients efficiently. It may create a continuous nutritional balance in the different growth stages of the rice plant especially nano material which stimulates crop growth, improve the soil environment and promote crop growth metabolism. Especially, the increase in plant height by the application of nano-fertilizer and its physiological role in stimulating porphyrin molecules and important metabolic compounds such as chlorophyll and cytochrome pigments necessary for photosynthesis and respiration as well as co-enzymes that activate phosphorous which are essential for the function of many enzymes and the production of amino acids used in protein synthesis.

Table 2: Effect of Nano DAP fertilizer on yield attributes of rice

Treatment details		Number of effective tillers m^{-2}	Panicle length (cm)	Total number of grains $panicle^{-1}$	Number of filled grains $panicle^{-1}$	Number of chaffy grains $panicle^{-1}$	Test weight (g)
T_1	100% RDF as basal	184.87	22.07	149.07	143.07	6.00	22.53
T_2	25% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + one spray of Nano DAP at 25 DAT	152.07	16.60	136.20	128.00	8.20	21.87
T_3	25% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two spray of Nano DAP at 25 and 50 DAT	158.67	18.67	139.74	130.08	9.66	21.90
T_4	50% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + one spray of Nano DAP at 25 DAT	170.67	19.60	144.10	136.13	7.97	22.00
T_5	50% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two spray of Nano DAP at 25 and 50 DAT	175.53	21.50	145.60	138.83	8.47	22.33
T_6	75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + one spray of Nano DAP at 25 DAT	188.40	22.67	152.07	145.40	6.66	22.67
T_7	75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two spray of Nano DAP at 25 and 50 DAT	194.20	24.90	155.83	147.00	8.83	23.10
SEm (±)		5.44	0.96	2.51	2.33	0.96	0.56
CD (5%)		16.76	2.96	7.74	7.17	NS	NS

Yield

The grain yield and straw yield as influenced by the integrated use of Nano DAP and conventional fertilizers (presented in Table 3). Among the treatments imposed, application of 75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two foliar spray of Nano DAP at 25 and 50 DAT (T_7) recorded a significantly higher grain yield of 54.78 q ha^{-1} and straw yield of 57.33 q ha^{-1}. The higher grain yield and straw yield was obtained by the effective utilization of resources that increased the performance of the crop. These results conformed with the findings of Elavarasan *et al*., 2021 [36].

The influential role played by the nano form of DAP and their longer duration availability to the crop especially in the later stages (reproductive stage) increased the yield. Further, the active role of nano particles is integrated with other elements and act as a catalyst in increasing the enzymatic reactions due to their bulk surface area. In addition to that, the higher yield is associated with the combined use of nano DAP fertilizer with conventional fertilizers. This increased the availability and uptake of nutrients.

Table 3: Effect of Nano DAP fertilizer on grain yield, straw yield and harvest index of rice

Treatment details		Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Harvest index (%)
T_1	100% RDF as basal	46.78	48.33	48.55
T_2	25% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + one spray of Nano DAP at 25 DAT	28.65	30.00	49.50
T_3	25% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two spray of Nano DAP at 25 and 50 DAT	30.16	32.33	49.26
T_4	50% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + one spray of Nano DAP at 25 DAT	38.98	41.67	49.02
T_5	50% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two spray of Nano DAP at 25 and 50 DAT	42.56	44.68	48.78
T_6	75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + one spray of Nano DAP at 25 DAT	51.32	53.67	48.31
T_7	75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two spray of Nano DAP at 25 and 50 DAT	54.78	57.33	48.08
SEm (±)		3.01	3.29	1.81
CD (5%)		9.27	10.14	NS

Economics of rice

The economics of rice cultivation was influenced by the combined application of nano DAP and conventional fertilizer due to freuently supply of nutrient at the different growth stages of plant. Maximum gross income (Rs. 1,48,416 ha^{-1}), net income (Rs. 94,204 ha^{-1}) and benefit : cost ratio (1.74) was obtained by the application of 75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two spray of Nano DAP at 25 and 50 DAT (T_7).

Table 4: Effect of Nano DAP fertilizer on economics of rice

Treatment details		Cost of cultivation (kg ha^{-1})	Gross income (Rs. ha^{-1})	Net income (Rs. ha^{-1})	B:C ratio
T_1	100% RDF as basal	49,333	1,26,616	77,283	1.57
T_2	25% RDF of N and P through DAP and Urea as basal Root Dipping with Nano DAP + one spray of Nano DAP at 25 DAT	49,523	77,625	28,101	0.57
T_3	25% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two spray of Nano DAP at 25 and 50 DAT	52,088	81,866	29,777	0.57
T_4	50% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + one spray of Nano DAP at 25 DAT	50,585	1,05,784	55,199	1.09
T_5	50% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two spray of Nano DAP at 25 and 50 DAT	53,150	1,15,336	62,186	1.17
T_6	75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + one spray of Nano DAP at 25 DAT	51,646	1,39,034	87,387	1.69
T_7	75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two spray of Nano DAP at 25 and 50 DAT	54,211	1,48,416	94,204	1.74

Conclusion

The utilization of nano technology in the field of agriculture is still in its growing stage. An outrageous nutrient insufficiency in agricultural soil has realized exceptional decreases in viability of yield and a huge economic crisis. From the results, the application of 75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two foliar spray of Nano DAP at 25 and 50 DAT (T_7) was found to be optimum in terms of growth, development and yield of rice. In the nutshell, it can be concluded and recommended that the application of 75% RDF of N and P through DAP and Urea as basal + Root Dipping with Nano DAP + two foliar spray of Nano DAP at 25 and 50 DAT (T_7) could be a viable option for enhancing the productivity of rice.

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