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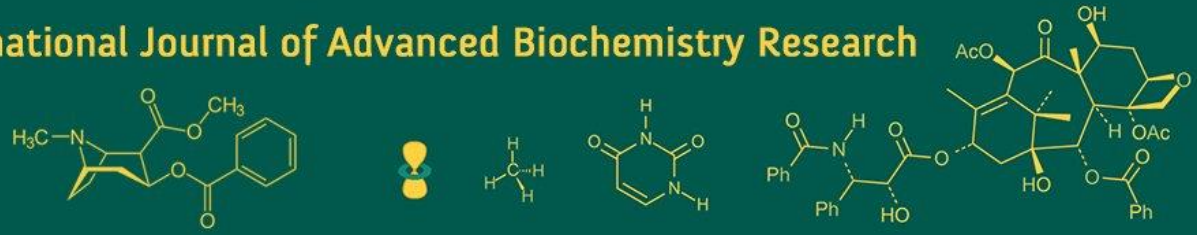

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Effect of foliar application of nano urea under different fertility levels on the yield and economics of rice (*Oryza sativa* L.)

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Abstract
The experiment was carried out in Split Plot Design with 16 treatment combinations of fertility levels as main plot *viz*., N_1- Control, N_2- 50% RDF, N_3- 75% RDF and N_4- 100% RDF with foliar application of nano urea treatment as sub plot *viz*., S_1- Nano urea spray one time (20-25 DAT @ 5 ml L^{-1} water), S_2- Nano urea spray two times (20-25 DAT & 40-45 DAT @ 5 ml L^{-1} water), S_3- Urea spray one time (20-25 DAT @ 20 g L^{-1} water) and S_4- Urea spray two times (20-25 DAT & 40-45 DAT @ 20 g L^{-1} water) were replicated thrice at DKS College of Agriculture and Research Station, Bhatapara, Chhattisgarh. The results of this experiment reveals that grain and straw yield (kg ha^{-1}) of rice were found significantly superior under treatment N_4- 100% RDF followed by N_3- 75% RDF. Among the foliar application of nano urea, grain yield and straw yield were recorded significantly higher in treatment S_2- Nano urea spray two times (20-25 DAT & 40-45 DAT @ 5 ml L^{-1} water) followed by S_4- Urea spray two times (20-25 DAT & 40-45 DAT @ 20 g L^{-1} water). In case of fertility levels, the value of Gross return (₹ ha^{-1}), Net return (₹ ha^{-1}) and B:C ratio were recorded significantly highest under treatment N_4-100% RDF followed by treatment N_3- 75% RDF. Among the foliar application of nano urea treatments, value of Gross return (₹ ha^{-1}), Net return (₹ ha^{-1}) were recorded significantly higher under treatment S_2- Nano urea spray two times (20-25 DAT & 40-45 DAT @ 5 ml L^{-1} water) and highest B:C ratio were recorded significantly highest under treatment S_4- Urea spray two times (20-25 DAT & 40-45 DAT @ 20 g L^{-1} water). Whereas Lowest value of Gross return, Net return and B:C ratio were noticed in treatment N_1- control and S_3- Urea spray one time (20-25 DAT @ 20 g L^{-1} water).

Keywords: Rice (*Oryza sativa* L.), yield, economics

Introduction
Rice (*Oryza sativa* L.) is one of the most important cereal crops. It is a plant of South East Asia origin. It belongs to family Poaceae (Gramineae). The genus *Oryza* includes 24 species, of which 22 are wild and two species namely *Oryza sativa* and *Oryza glaberrima* are cultivated. All the varieties found in Asia, America and Europe belong to *Oryza sativa* and varieties found in West Africa belong to species *Oryza glaberrima*. Rice is primarily a high-energy or high calorie food. The protein content of milled rice is usually 6 to 7 per cent. Rice is enriched in the vitamin's thiamine, riboflavin and niacin. The amino acid profile of rice reveals that it is high in glutamic and aspartic acid (FAO, 2004) [4]. Rice contains 80% carbohydrates, 7-8% protein, 3% fat and 3% fiber. Globally, rice is cultivated in 165.25 million ha area with an annual production of around 787.30 million tonnes with yield of 4.76 tonnes ha^{-1} [Anonymous. 2021(a)] [1]. In India, cultivated area about 45.07 million hectares with an annual production of about 122.27 million tonnes and productivity of 2713 kg ha^{-1} [Anonymous. 2021(b)] [2]. In the Chhattisgarh state, Paddy cultivated area is 3.79 million hectares with production of 7.1 million tonnes and yield of paddy is 1889 kg ha^{-1} [Anonymous. 2021(c)] [3].

Increasing farmers' incomes is the primary task in agriculture. Reducing cultivation costs or raising crop yields are two ways we can help farmers make more money. Improved crop yields are dependent on appropriate nutrient management, or the administration of the right kind and quantity of fertilizers at the right time (dosage). The cost of cultivation and crop output are directly impacted by varying nitrogen sources and dosages. By reducing the money needed to purchase additional fertilizer and apply it, the precise amount of nitrogen

from the right sources can help lower the cost of cultivation. Therefore, choosing the right nitrogenous fertilizer and making adjustments to fertilizer application or nutrient management techniques can be crucial to boosting rice production and ensuring that future generations' rice demands are met. Large amounts of fertilizers are currently used to produce food, as they are essential for crop productivity. However, sometimes their high cost, which is beyond the reach of marginal farmers, particularly in developing countries becomes a challenge to be faced by farmers.

The application of nano-fertilizers (NFs) is an emerging research field in agriculture. These substances, which range in size from 1 to 100 nm, aid in the plants nutrition. As an alternative to traditional urea fertilizer, nano urea is a liquid formulation of urea based on nanotechnology that supplies nitrogen to plants. According to IFFCO guidelines, a 500 ml bottle of nano urea is sufficient for one acre. Foliar application of nano urea (Liquid) at critical crop growth stages of a plant effectively fulfils its nitrogen requirement and leads to higher crop productivity and quality in comparison to conventional urea. It is a sustainable solution for plant nutrition with higher nutrient use efficiency and reduces soil, water, and air pollution. It was also reported for substantial increase in farmers income.

Materials and Methods

The present investigation was conducted at Instructional Farm, DKS College of Agriculture and Research Station, Bhatapara, Chhattisgarh during the *Kharif* season 2023 to find the effect of foliar application of nano urea under different fertility levels on rice (*Oryza sativa* L.)". The typical climatic condition of Bhatapara is hot and humid and the soil texture at the field experiment site is clayey. The total rainfall received during crop growth period was 1339.4 mm. Relative humidity ranged between 92% to 83.1%. The mean weekly maximum and minimum temperature during the crop growth period ranged between 28.8 to 33.7ºC and 11.8 to 25.7ºC respectively. Wind speed varied from 1 to 6.4 km hr^{-1}. The average and cumulative open pan evaporation during study period was 14.6 and 29.6 mm respectively. The bright sunshine varied from 0.8 to 9.2 hrs day^{-1}.

Sixteen treatment combinations comprising of four differnent fertility levels as main plot *viz*., N_1- Control, N_2- 50% RDF, N_3- 75% RDF and N_4- 100% RDF with foliar application of nano urea treatment as sub plot *viz*., S_1- Nano urea spray one time (20-25 DAT @ 5 ml L^{-1} water), S_2- Nano urea spray two times (20-25 DAT & 40-45 DAT @ 5 ml L^{-1} water), S_3- Urea spray one time (20-25 DAT @ 20 g L^{-1} water) and S_4- Urea spray two times (20-25 DAT & 40-45 DAT @ 20 g L^{-1} water) were replicated thrice in Split Plot Design taken under study to estimate response in yield and economics of rice.

The rice variety mahamaya were transplanted at spacing 20 cm × 10 cm (row × plant). The gross and net plot size was 4 m × 4 m and 3.2 m × 3.2 m, respectively. The Recommended dose (100 kg N + 60 kg P_2O_5 + 40 kg K_2O ha^{-1}) was provided as urea, diammonium phosphate and muriate of potash, in that order. Weed control practices were done by hand weeding at 30 DAT and 60 DAT. Although there were adequate amounts of rainfall during the testing period, the crop received two irrigations during the blossoming and grain filling stages. At physiological maturity, the grains were harvested under sufficiently harsh conditions, with less than 16 percent moisture content. Each net plot's harvested bundle was weighed after it had been exposed to the sun in order to record grain yield and straw yield following winnowing. The unit of measurement for both grain and straw yield was kg ha^{-1}. Harvest index and economics were worked out using the following formulas:

a) $HI\ (\%) = \frac{\text{Economic yield (kg ha}^{-1})}{\text{Biological yield (kg ha}^{-1})} \times 100$

b) Net returns (₹ ha^{-1}) = Gross returns (₹ ha^{-1}) - Cost of cultivation (₹ ha^{-1})

c) $B:C = \frac{\text{Gross returns (₹ } ha^{-1})}{\text{Cost of cultivation (₹ } ha^{-1})}$

Result and Discussion

Yield

The fertility levels and foliar application of nano urea both exerted significant effect on grain yield and straw yield. The results revealed that the maximum grain and straw yield was recorded under N_4- 100% RDF which was followed by N_3- 75% RDF > N_2- 50% RDF > N_1- Control. The control treatment yielded the lowest since it did not apply fertilizer. These results emphasise how important it is to apply fertilizer correctly in order to maximise rice output. The results obtained in the present study are supported by the works of Valojai *et al.* (2021) [6]. Also, the maximum grain and straw yield was recorded under S_2- Nano urea spray two times (20-25 DAT & 40-45 DAT @ 5 ml L^{-1} water) followed by S_4- Urea spray two times (20-25 DAT & 40-45 DAT @ 20 g L^{-1} water) > S_1- Nano urea spray one time (20-25 DAT @ 5 ml L^{-1} water) > S_3- Urea spray one time (20-25 DAT @ 20 g L^{-1} water). The findings highlight how crucial it is to apply nano urea for appropriate nutrient management in order to maximise rice yield and improve harvest quality. The finding of present study is in accordance with those of Midde and ferumal (2021) [5] and Valojai *et al.* (2021) [6].

Significantly, highest harvest index was recorded in treatment N_4- 100% RDF followed by N_3- 75% RDF > N_2- 50% RDF > N_1- Control. Significant increases in yield parameters were also observed in treatment N_4- 100% RDF as compared to the Control treatment, emphasising the crucial importance of applying a sufficient amount of fertiliser. The research conducted by Valojai *et al.* (2021) [6] provides support for the findings of the current investigation. Also, the maximum harvest index recorded under S_2- Nano urea spray two times (20-25 DAT & 40-45 DAT @ 5 ml L^{-1} water) followed by S_4- Urea spray two times (20-25 DAT & 40-45 DAT @ 20 g L^{-1} water) > S_3- Urea spray one time (20-25 DAT @ 20 g L^{-1} water) > S_1- Nano urea spray one time (20-25 DAT @ 5 ml L^{-1} water). The relevant data of grain yield, straw yield and harvest index were presented in Table 1.

Economics

The fertility levels and foliar application of nano urea both exerted significant effect on economics of rice. The results revealed that the maximum cost of cultivarion, gross returns (₹ ha^{-1}) and net returns (₹ ha^{-1}) were recorded under N_4- 100% RDF which was followed by N_3- 75% RDF > N_2- 50% RDF > N_1- Control. Also, the maximum cost of cultivarion, gross returns and net returns were recorded under S_2- Nano urea spray two times (20-25 DAT & 40-45

DAT @ 5 ml L^{-1} water) followed by S_4- Urea spray two times (20-25 DAT & 40-45 DAT @ 20 g L^{-1} water) > S_1- Nano urea spray one time (20-25 DAT @ 5 ml L^{-1} water) > S_3- Urea spray one time (20-25 DAT @ 20 g L^{-1} water).

Significantly highest B:C ratio was recorded in treatment were recorded in treatment N_4- 100% RDF which was followed by N_3- 75% RDF > N_2- 50% RDF > N_1- Control. Among the foliar spray of nano urea, highest B:C ratio was recorded in treatment were recorded in treatment S_4- Urea spray two times (20-25 DAT & 40-45 DAT @ 20 g L^{-1} water) followed by S_2- Nano urea spray two times (20-25 DAT & 40-45 DAT @ 5 ml L^{-1} water) > S_1- Nano urea spray one time (20-25 DAT @ 5 ml L^{-1} water) > S_3- Urea spray one time (20-25 DAT @ 20 g L^{-1} water). The relevant data of economics of rice were presented in Table 2.

Table 1: Grain yield, straw yield and harvest index of rice as influenced by fertility levels and foliar spray of nano urea

Treatments	Grain yield (Kg ha^{-1})	Straw yield (Kg ha^{-1})	Harvest index (%)
Fertility Levels			
N_1 : Control	3368	4733	41.6
N_2 : 50% RDF	4933	6142	44.5
N_3 : 75% RDF	5396	6453	45.5
N_4 : 100% RDF	5722	6783	45.7
SEm±	111	160	1.01
CD (0.05)	383	553	3.50
Foliar spray of nano urea			
S_1 : Nano urea spray one time (20-25 DAT @ 5 ml L^{-1} water)	4595	5798	44.0
S_2 : Nano urea spray two times (20-25 DAT & 40-45 DAT @ 5 ml L^{-1} water)	5260	6366	44.8
S_3 : Urea spray one time (20-25 DAT @ 20 g L^{-1} water)	4461	5619	44.2
S_4 : Urea spray two times (20-25 DAT &40-45 DAT @ 20 g L^{-1} water)	5101	6328	44.4
SEm±	75	77	0.55
CD (0.05)	218	225	NS
Interaction			
SEm±	149	154	1.10
CD (0.05)	436	450	NS

Table 2: Economics of rice as influenced by fertility levels and foliar spray of nano urea

Treatments	Cost of Cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C
Fertility Levels				
N_1 : Control	33331	81184	47853	2.44
N_2 : 50% RDF	37007	117733	80725	3.18
N_3 : 75% RDF	38624	128385	89760	3.32
N_4 : 100% RDF	40242	136048	95805	3.38
SEm±	-	2437	2437	0.07
CD (0.05)	-	8433	8433	0.24
Foliar spray of nano urea				
S_1 : Nano urea spray one time (20-25 DAT @ 5 ml L^{-1} water)	37104	109788	72683	2.94
S_2 : Nano urea spray two times (20-25 DAT & 40-45 DAT @ 5 ml L^{-1} water)	38483	125267	86784	3.22
S_3 : Urea spray one time (20-25 DAT @ 20 g L^{-1} water)	36447	106576	70129	2.91
S_4 : Urea spray two times (20-25 DAT &40-45 DAT @ 20 g L^{-1} water)	37171	121719	84548	3.24
SEm±	-	1628	1628	0.04
CD (0.05)	-	4752	4752	0.13
Interaction				
SEm±	-	3256	3256	0.09
CD (0.05)	-	9503	9503	0.25

Conclusion

Highest grain yield, straw yield and harvest index was obtained in treatment N4- 100% RDF + S_2- Nano urea spray two times (20-25 DAT & 40-45 DAT @ 5 ml L^{-1} water). The gross return (₹ ha^{-1}) and net return (₹ ha^{-1}) were also recorded higher with N4- 100% RDF + S_2- Nano urea spray two times (20-25 DAT & 40-45 DAT @ 5 ml L^{-1} water). While higher B:C ratio was recorded in treatment N_4- 100% RDF + S_4- Urea spray two times (20-25 DAT & 40-45 DAT @ 20 g L^{-1} water).

Hence it can be cancluded that 100% fertilizer application + Nano urea spray two times (20-25 DAT & 40-45 DAT @ 5 ml L^{-1} water) and 100% fertilizer application + Urea spray two times (20-25 DAT & 40-45 DAT @ 20 g L^{-1} water) is beneficial for higher rice productions.

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