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Effect of Nano Urea (liquid) on yield and fertilizer saving in rice under island ecosystem

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ABSTRACT

In recent years, there is a growing compulsion to address the issue of stagnant input response and growing environment concerns. Thus a field experiment was conducted during 2021 at two farmer's field viz., Guptapara (South Andaman) and Nimbudera (Middle Andaman) to study the effect of nano urea (liquid) on the growth, yield, economics and nutrient use efficiency of rice under island conditions. There were 6 treatments viz., N_0PK, $N_{100}PK$, $N_{50}PK$ + Nano Urea (0.2%), $N_{75}PK$ + Nano Urea (0.2%), $N_{50}PK$ + Nano Urea (0.4%) and N_{75} PK + Nano Urea (0.4%). Nano urea (liquid) was sprayed two times at 0.2 % and 0.4 % concentrations. The recommended dose of fertilizers was 90:60:60 NPK kg/ha. The paddy varieties *viz.*, CIARI Dhan 2 (Medium duration) and ANR 40 (long duration) were used at Guptapara and Nimbudera, respectively. The results revealed that application of nano urea (liquid) spray with conventional fertilizer had significant impact on growth, yield attributes and yield of rice at both the farmer's field. Further, nano spray (N_{75}PK and 0.4 % Nano urea) contributes to additional yield of 16.6 and 12 % and additional monetary benefit of Rs. 12,598 and 8091 in Guptapara and Nimbubdera, respectively than only NPK addition through chemical fertilizers (100 % RDF). Further, there is little difference between nano spray at 0.2 % and 0.4% spray though higher concentration of (0.4%) nano spray gave 3.7 and 5.4 % higher yield and 9.0 and 9.2 % higher net return in Guptapara and Nimbubdera, respectively. Nano urea spray with N_{50} and N_{75} had significant effect on Partial factor productivity, Nitrogen use efficiency (NUE crop) and Agronomic efficiency. The increased efficiency of nano urea resulted in saving of mineral urea when compared to the chemical fertilizer application to the extent of 25 % at farmers' field. At the same time increasing the concentration of Nano spray from 0.2 to 0.4% had no impact on the saving without increasing the N addition. Spraying of nano urea can increase crop yield by increasing the nutrient uptake by plants and its bioavailability in soil. Spraying of nano urea is proved to be beneficial for island ecosystem as it lead to saving of chemical fertilizer thereby reducing the accumulation of N in the environment.

Key words: *Nano urea, Rice and Island ecosystem*

Introduction

Urea contributes about 82 per cent of the total fertilizer consumption in India and about 55 per cent of the total fertilizer nitrogen consumed in the world. Around 30- 40 per cent of nitrogen from urea is utilized by plants and the rest gets wasted. The high N loss coupled with its low use efficiency forced the farmers to increase the amounts of applied N fertilizers in order to achieve better crop production (Rathnayaka *et al*., 2018), which resulted in rising the costs of the farming practice, meanwhile, increasing

the consequent environmental implications (Chhowalla, 2017; Marchiol, 2019). Excessive N application in agriculture through bulk chemical fertilizers has to be reduced in a phased manner for ensuring healthy environment and sustaining soil-crop-atmospheric biodiversity. Due to growing challenges in Indian Agriculture, interest in nano technology has been increased with the goals to increase crop production and to increase resource use efficiency. Nanotechnology, which utilizes nanomaterials of less than 100 nm size, has emerged as an innovative science to develop concentrated sources of plant nutrients having higher-absorption rate, utilization efficacy, and minimum losses (Yogendra Kumar *et al*., 2021). More importantly, the nano formulated nutrient hold great promise for application in plant nourishment because of the size-dependent qualities, high surface-volume ratio, and unique optical properties. Because of high surface area to volume ratio, the effectiveness of nano fertilizers may surpass the conventional fertilizers (Naderi and Danesh-Shahraki, 2013). Nano fertilizers with nano formulated particles elements can directly supply the essential plant nutrients and can be delivered at time and dose required by crops at rhizosphere (Subramanian and Tarafdar, 2011). This ultimately results in input efficiency and less harm to the environment compared the chemical fertilizer.

India is the one of the largest producer and consumer of rice in the world. Over the last 15 years (2005-2020), rice production in India increased from around 80.0 m.t. in 2005 to around 121 m.t. in 2020 (Economic survey 2005-2020). It was made possible mostly by increased inputs use besides exploitation of genetic resources. However, deterioration of soil fertility has been widely reported to be the major cause for stagnating rice productivity in India. The input response or factor productivity is reported to be declining in major rice growing states. In Andaman and Nicobar Islands also, rice is the most important crop after plantation crops. Therefore, increasing rice production requires increased rice productivity and efficiency. In this context, the use of nano urea is expected to improve the input efficiency and enhance the productivity and reduce the environmental concerns. The development of nano urea (liquid) by IFFCO for agricultural use has a pretty good prospect to be able to answer the challenge of precisely providing nutrients from plants through more efficient nutrient delivery system. IFFCO nano urea liquid contains 40,000 ppm of nitrogen in a 500 ml bottle which is equivalent to the impact of nitrogen provided by one bag of conventional urea and replace conventional urea by 50 %. Nano urea is more efficacious in terms of nutrient absorption owing to lesser losses. When sprayed on leaves at critical crop growth stages, nano urea easily enters through stomata and other openings and is assimilated by the plant cells. At the same time, it is essential to understand its efficiency over chemical fertilizer in field condition. This is essential to minimize the chemical fertilizer use and increase the nano urea without compromising the yield particularly in the island ecosystem. Under this context, the field experiment was conducted to study the effect of nano urea in reducing the application of urea and increasing the productivity and profitability of rice in tropical island conditions.

Materials and Methods

The Andaman and Nicobar islands receive an annual rainfall of more than 3000 mm with the mean maximum and minimum temperature of 32 °C to 22 °C, respectively. The relative humidity varies from 68 to 86 %. The wet season (June-December) is characterized by monsoonal rainfall associated with deep depressions and tropical cyclones. Low input rainfed agriculture is the major occupation and in general crop yields are low as compared to mainland. In the coastal lowlands, rice is the only crop grown during wet season, while pulses and vegetables are commonly grown after harvest of rice. The initial soil was slightly acidic, low in electrical conductivity, high in soil organic carbon and low in N, P and K content. In this study, IFFCO nano urea (liquid) was used. In order to evaluate the effect of nano urea (liquid) a field experiment was conducted during June-December, 2021 in a randamized block design at two farmer's field viz., Guptapara and Nimbudera villages located at South Andaman and Middle Andaman, respectively. There were 6 treatments viz., N_0PK, $N_{100}PK$, $N_{50}PK$ + Nano Urea (0.2 %), $N_{75}PK$ + Nano Urea (0.2 %), $N_{50}PK$ + Nano Urea (0.4 %) and $N_{75}PK$ + Nano Urea (0.4 %). Nano urea (liquid) was sprayed two times at 0.2 % and 0.4 % concentrations. The recommended dose of fertilizers was 90:60:60 NPK kg/ha. The paddy varieties *viz.,* CIARI Dhan 2 (Medium duration) and ANR 40 (long duration) were used at Guptapara and Nimbudera, respectively. In the experiment, Urea, DAP and MOP were used to supply N, P and K re-

spectively. In addition, 2.0 ml (0.2 %) and 4.0 ml (0.4%) of Nano urea (Liquid) in one litre of water was mixed and sprayed on crop leaves at active tillering and panicle initiation stages. Plant growth parameters like plant height, total no of tillers, productive tillers, days to 50 % flowering, dry matter production, panicle length, no of grains per panicle, 1000 grain weight, yield/m^2 and yield/ha were recorded. Soil and plant samples were collected from the experimental plots and analysed for nutrient uptake and available nutrient status.

Results and Discussion

Growth attributes

The results have shown that the application of nano urea (liquid) spray with conventional fertilizer had significant impact on growth of rice at both the farmer's field (Table 1 and 2). Nano spray contributes to the increased growth attributes than only NPK addition through chemical fertilizers. Application of 75 % nitrogen (N_{75} PK) and foliar spray of nano urea (0.4 %) recorded higher plant height (113 cm) and at par with 100% recommended dose of fertilizers. Similarly, application of 75 % nitrogen (N_{75} PK) and foliar spray of nano urea (0.4 %) recorded higher shoot (30.1 g) and root (7.9 g) weight and at par with N_{75} PK + 0.2 % nano urea spray. Increased concentration of nano spray (0.4%) had significant impact on the plant growth parameters due to increased availability of N within the plant system. Further, the shoot and root weight were slightly increased when nano urea (0.2 to 0.4 %) is sprayed at maximum tillering and panicle initiation stage along with reduced level (75 % and 50 %N) of fertilizer and at par with N_{100} PK. The primary reason for better performance of rice receiving two nano sprays was due to nano-pores and stomatal openings in plant leaves which facilitated nano material uptake and their penetration inside leaves leading to higher nutrient use efficiency. Precisely nano fertilizers have higher transport and delivery of nutrients through plasmodesmata, which are nano sized (50-60 nm) channels between cells (Mahanta *et al*., 2019). The results were in agreement with the findings of Sai Kumar Midde *et al***.,** 2022.

Table 1. Effect of nano urea on growth parameters of rice at Guptapara, South Andaman

Treatments	Plant height (cm) at harvest	Root weight (g)	Shoot weight (g)
T_1- N_0PK	91	6.9	24.2
T_2- N_{100} PK	106	7.4	26.6
T_3- N_{50} PK+ Nano 0.2 %	95	7.5	24.8
T_4- N_{75}PK+ Nano 0.2 %	101	7.8	27.2
T_5- N_{50} PK+Nano 0.4 %	99	7.6	25.4
T_6- N_{75}PK+Nano 0.4 %	113	7.9	30.1
CD (0.05)	10.0	0.52	2.13

Table 2. Effect of nano urea on growth parameters of riceat Nimbudera, Middle Andaman

Treatments	Plant height (cm) at harvest	Root weight (g)	Shoot weight (g)
T_1- N_0PK	97	6.8	24.1
T_2- N_{100} PK	113	7.3	26.4
T_3- N_{50} PK+ Nano 0.2 %	101	7.5	24.8
T_4- N_{75}PK+ Nano 0.2 %	108	7.6	26.7
T_5- N_{50} PK+Nano 0.4 %	105	7.6	25.4
T_6- N_{75}PK+Nano 0.4 %	119	7.9	29.8
CD (0.05)	13.2	0.53	2.12

Yield attributes and yield

The results showed that split application of fertilizers and nano urea spray have significant effect on yield attributes and grain yield of rice at both the locations (Table 3 & 4).

At Guptapara farmer's field, application of N_{75}PK followed by foliar spray of 0.4 % nano urea recorded more number of tillers/plant and at par with 100 % RDF and other nano urea treatments except control. Similarly, application of N_{75}PK + 0.4 % nano urea spray recorded maximum panicle length (24.3 cm) and no. of panicles/m^2 (150) and at par N_{75}PK +0.2 % nano urea spray and 100 % RDF. While, reduced N levels at both nano urea concentration (0.2 and 0.4 %) and control recorded lesser panicle length and no. of panicles/m^2. Thousand grain weights were not influenced by the nano urea treatments. Similarly, N_{75}PK with two nano spray (0.4%) gave significantly higher grain yield than 100% NPK application. It was also observed that increased concentration of nano spray (0.2% and 0.4%) had no significant effect without increasing the rate of N fertilizer addition (N_{50} and N_{75}). Application of 100% NPK fertilizer (T_2) and N_{75} with 2 nano spray (0.4%) produced significantly higher grain yield but lower than N_{75} with 0.2% spray. This means higher resource allocation for grain development with nano spray that resulted in higher grain yield than other

treatments. Similarly in Nimbudera, application of N_{75}PK with two nano spray (0.4%) gave significantly higher growth, yield attributes and yield of rice as compared to 100% NPK application through conventional fertilizer. This is agreement with the findings of Tosan Kumar Sahu *et al*., 2022, who reported higher yield of rice under treatment 75% of RDN + Two foliar sprays of nano urea (AT and PI)which was at par with treatment T4 50% of RDN + Two foliar sprays of nano urea (AT and PI) and T6 100% of RDN + Two foliar sprays of nano urea (AT and PI).Similarly, the experimental results on application of nano urea – liquid (nano N) across locations also revealed that two foliar applications at critical growth stages of crops led to a reduction in the application rate of fertilizer-N and also caused increase in the yield in range of: 3-23% in wheat, 3-24% in paddy/rice and 2-15% in maize (Yogendra Kumar *et al*., 2021).

Economics

The economics of rice was significantly influenced by nano urea spray at both the locations (Table 5 and 6). It is estimated that 600- 1200 respectively were incurred as additional cost on account of application of nano spray (0.2 - 0.4%). However, the grain yield was slightly higher in nano urea sprayed treatment (N_{75}PK and 0.4 % Nano urea spray) than 100 % NPK. Hence, application of N_{75}PK and 0.4 % Nano urea sprayrecorded higher net return of 57546 and Rs. 46890 with additional monetary benefit of 12598 and 8091 as compared to 100 % NPK application in Guptapara and Nimbudera, respectively. Further, there is only little difference between Nano spray at 0.2 % and 0.4% spray though higher concentration of (0.4%) nano spray gave 9.0 and 9.2 % higher netreturn in Guptapara and Nimbubdera, respectively. Similarly, application of N_{75}PK and 0.4 % Nano urea spray recorded higher B: C ratio as compared to 100 % chemical fertilizer application in both the locations.

Nutrient use efficiency

Several researchers have reported that nano fertilizers have higher transport and delivery of nutrients through plasmadesmata, which are nano sized (50–60 nm) channels between cells. Consequent to the increased N application efficiency and utilization efficiency of 2 nano spray (0.4%) resulted in higher yield and reduced loss into the environment. Results confirm that NUE can be improved by synchronizing the nutrient availability as per the need of the crops (Velmurugan *et al*., 2021). Here, foliar application of nano fertilizers at critical growth stages of

Table 3. Effect of nano urea on rice yield attributes at Guptapara, South Andaman

Treatments	Total no of tillers	Panicle length (cm)	No of panicles/m²	1000 grain wt	Grain yield (kg/ha)	Straw yield (kg/ha)
T_1- N_0PK	129	20.0	124	23	3015	4834
T_2- N_{100}PK	146	23.3	140	23	3611	5795
T_3- N_{50} PK+ Nano 0.2 %	144	20.6	132	24	3493	5604
T_4- N_{75}PK+ Nano 0.2 %	150	24.0	144	24	4019	6450
T_5- N_{50}PK+ Nano 0.4 %	146	20.8	134	24	3580	5743
T_6- N_{75}PK+ Nano 0.4 %	157	24.3	150	24	4213	6759
CD (0.05)	15.9	3.3	15.4	NS	514	763

Table 4. Effect of nano urea (liquid) on rice yield attributes at Nimbudera, Middle Andaman

Treatments	Total no of tillers	Panicle length (cm)	No of panicles/m²	1000 grain wt	Grain yield (kg/ha)	Straw yield (kg/ha)
T_1- N_0PK	150	19.8	145	19.77	2875	4274
T_2- N_{100}PK	165	23.3	159	20.75	3373	5023
T_3- N_{50} PK+ Nano 0.2 %	154	21.9	149	20.82	3174	4719
T_4- N_{75}PK+ Nano 0.2 %	159	24.6	154	20.98	3572	5313
T_5- N_{50} PK+Nano 0.4 %	156	23.0	150	20.59	3332	4962
T_6- N_{75}PK+Nano 0.4 %	166	26.1	160	20.92	3780	5627
CD (0.05)	10.8	2.7	10.1	NS	366	798

crops can provide opportunity for improving nutrient utilisation, arresting/minimising nutrient losses from the crop production system. This is in agreement with the findings of Kumar *et al*., 2021 and Lahari *et al*., 2021. Nano urea application recorded higher partial factor productivity, agronomic efficiency, nutrient use efficiency and nitrogen saving in rice (Table 7 & 8). Hayyawi *et al*., 2019 also reported higher fertilizer use efficiency (FUE) and agronomic use efficiency (AUE) in potato when nano NPK fertilizers are applied. Nano urea spray with N_{50} and N_{75} had significant effect on Partial factor productivity, Nitrogen use efficiency (NUE crop) and Agronomic efficiency. The increased efficiency of nano

Table 5. Economics of rice as influenced by nano urea spray at Guptapara

Treatments	Cost of cultivation (₹)	Gross return(₹)	Net return(₹)	B: C ratio
T_1- N_0PK	35920	68153	32233	1.90
T_2- N_{100} PK	36689	81637	44948	2.23
T_3- N_{50} PK+ Nano 0.2 %	36907	79121	42214	2.14
T_4- N_{75}PK+ Nano 0.2 %	37098	88030	50932	2.37
T_5- N_{50}PK+Nano 0.4 %	37507	81526	44020	2.17
T_6- N_{75}PK+Nano 0.4 %	37698	95244	57546	2.53

Table 6. Economics of rice as influenced by nano urea spray at Nimbudera

Treatments	Cost of cultivation(₹)	Gross return(₹)	Net return(₹)	B: C ratio
T_1- N_0PK	35920	64320	28400	1.79
T_2- N_{100} PK	36689	75488	38799	2.06
T_3- N_{50} PK+ Nano 0.2 %	36907	71015	34108	1.92
T_4- N_{75}PK+ Nano 0.2 %	37098	79916	42819	2.15
T_5- N_{50}PK+Nano 0.4 %	37507	74558	37051	1.99
T_6- N_{75}PK+Nano 0.4 %	37698	84587	46890	2.24

Table 7. Nitrogen use efficiency indices calculated for different treatments at Guptapara, South Andaman

Treatments	N applied (Kg/ha)	Partial Factor Productivity	NUE_{crop}	Agronomic Efficiency	Nitrogen Saving in Top Dressed Nitrogen Only	
					Kg (Frdf - Fnano)	E % T (E/ Frdf × 100)
T_1- N_0PK	0.0	-	-	-	-	-
T_2- N_{100} PK	90.0	40.1	0.49	6.6	-	-
T_3- N_{50} PK+ Nano 0.2 %	45.0	77.6	0.86	10.6	45.0	50.0
T_4- N_{75}PK+ Nano 0.2 %	67.5	59.5	0.67	14.9	22.5	25.0
T_5- N_{50}PK+Nano 0.4 %	45.05	79.5	0.86	12.5	44.9	49.9
T_6- N_{75}PK+Nano 0.4 %	67.5	62.4	0.80	17.7	22.5	25.0

Table 8. Nitrogen use efficiency indices calculated for different treatments at Nimbudera, Middle Andaman

Treatments	N applied (Kg/ha)	Partial Factor Productivity	NUE_{crop}	Agronomic Efficiency	Nitrogen Saving in Top Dressed Nitrogen Only	
					Kg (Frdf - Fnano) E	% T(E/Frdf × 100)
T_1- N_0PK	0.0	-	-	-	-	-
T_2- N_{100} PK	90.0	37.5	0.45	5.5		
T_3- N_{50} PK+ Nano 0.2 %	45.0	70.5	0.80	6.6	45.0	50.0
T_4- N_{75}PK+ Nano 0.2 %	67.5	52.9	0.61	10.3	22.5	25.0
T_5- N_{50}PK+Nano 0.4 %	45.05	74.0	0.86	10.1	44.9	49.9
T_6- N_{75}PK+Nano 0.4 %	67.5	56.0	0.66	13.4	22.5	25.0

Table 9. Initial and final soil properties of the experimental field at Guptapara, South Andaman

Soil Properties	Initial	After rice harvest					
		T_1	T_2	T_3	T_4	T_5	T_6
pH	7.42	7.46	7.58	7.40	7.45	7.33	7.46
EC (d Sm^{-1})	0.28	0.95	0.62	0.71	0.84	0.62	0.59
Organic Carbon (%)	0.69	0.65	0.68	0.63	0.60	0.64	0.68
Available N (kg ha^{-1})	158	115	146	121	130	141	140
Available P (kg ha^{-1})	8.61	8.58	8.92	8.28	8.08	8.18	7.98
Available K (kg ha^{-1})	120	119	132	133	130	129	131

Table 10. Initial and final soil properties of the experimental field at Nimbudera, Middle Andaman

Soil Properties	Initial	After rice harvest					
	T_1	T_2	T_3	T_4	T_5	T_6	
pH	6.1	6.08	5.85	6.15	6.00	5.91	6.15
EC (d Sm^{-1})	0.18	0.16	0.15	0.14	0.16	0.15	0.19
Organic Carbon (%)	0.70	0.68	0.65	0.69	0.70	0.71	0.68
Available N (kg ha^{-1})	145	120	142	137	139	142	147
Available P(kg ha^{-1})	8.75	8.10	9.12	8.30	8.60	8.02	8.82
Available K(kg ha^{-1})	120	114	132	122	131	130	136

urea resulted in saving of mineral urea when compared to the chemical fertilizer application to the extent of 25 to 50 % at farmers' field. At the same time increasing the concentration of Nano spray from 0.2 to 0.4% had no impact on the saving without increasing the N addition.

Soil available nutrient status

In this experiment soil pH, EC, OC, Available N, P and K were studied before sowing and after rice harvest (Table 9 and 10). There is no significant change in any of the soil properties but negative balance for soil available N was observed with the decrease in rate of N addition (50 and 75% of RDF). The soil properties were not much influenced by various nano urea treatments, but inorganic (100 NPK) application lowered the pH and increased the soil N content than foliar spray in combination with basal application of NPK.

Conclusion

For nano urea spray at 0.2 % and 0.4 %, additional costs of 600- 1200 were incurred. However, the nano spray (N_{75}PK and 0.4 % Nano urea) contributes to additional rice yield of 16.6 and 12 % and additional monetary benefit of 12,598 and 8091 in Guptapara and Nimbubdera, respectively than only NPK addition through chemical fertilizers (100 % RDF). Further, there is little difference between Nano spray at 0.2 % and 0.4% spray though higher concentration of (0.4%) nano spray gave 3.7 and 5.4 % higher yield and 9.0 and 9.2 % higher net return in Guptapara and Nimbubdera, respectively. Further, the increased efficiency of nano urea is resulting in saving of mineral urea to the extent of 25 %at experimental conditions. Spraying of nano urea can increase crop yield by increasing the nutrient uptake by plants and its bioavailability in soil. Spraying of nano urea is proved to be beneficial for island ecosystem as it lead to saving of chemical fertilizer thereby reducing the accumulation of N in the environment.

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