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Influence of fertilizer deep placement and nano urea on Growth, Yield and Economics of transplanted *kharif* rice

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Abstract
A field experiment was conducted during the *kharif* seasons of 2022 and 2023 at the Instructional-cum-Research Farm, Assam Agricultural University, Jorhat, to evaluate different nitrogen management practices on transplanted rice under rainfed conditions. The experiment was laid out in a Randomized Block Design with thirteen treatments and three replications, comprising different levels of recommended dose of nitrogen (RDN), nano-urea, and fertilizer deep placement (FDP).Results revealed that 125% RDN applied as FDP (T_{13}) recorded the highest plant height (130.76 cm at 60 DAT, 148.31 cm at 90 DAT and 146.26 cm at harvest), maximum number of tillers (330.16 and 347.92 m² at 60 and 90 DAT, respectively), and the highest dry matter accumulation (1528.14 g/m² at harvest). The same treatment also produced the highest pooled grain yield (53.04 q/ha) and straw yield (68.41 q/ha). The maximum cost of cultivation (₹50,380.58/ha), gross returns (₹146,253.82 /ha), net returns (₹95,873.24/ha), and benefit-cost ratio (1.90) was also recorded under 125% RDN as FDP. At early growth stage (30 DAT), the highest plant height (69.39 cm) was observed with 125% RDN + nano-urea (T_9).

Keywords: Nanourea, Conventional Urea, Growth, LAI, Yield and Wheat.

Introduction
Rice (*Oryza sativa* L.) is one of the most important staple food crops in the world, providing primary dietary energy for more than half of the global population. In India, rice occupies a major share of the cultivated area and plays a crucial role in ensuring food security and rural livelihoods, particularly in rainfed ecosystems where productivity is often constrained by nutrient limitations and erratic rainfall. Efficient nutrient management, especially nitrogen fertilization, is essential for sustaining rice productivity under such conditions. Nitrogen is a key macronutrient required for plant growth and development, as it directly influences chlorophyll formation, photosynthesis, tillering, biomass production, and grain yield in rice (Fageria *et al.*, 2008) [3]. However, conventional nitrogen application methods often result in low nitrogen use efficiency due to losses through volatilization, leaching, denitrification, and runoff, particularly under flooded or rainfed environments. Therefore, improving nitrogen use efficiency through innovative application methods has become a major research priority in rice-based production systems. Fertilizer deep placement (FDP) has emerged as an effective nitrogen management strategy that places fertilizer directly in the root zone, reducing nutrient losses and improving nitrogen recovery efficiency. Several studies have reported that FDP enhances tillering, biomass accumulation, and grain yield in rice compared to conventional broadcast application (Bandaogo *et al.*, 2015; Wang *et al.*, 2022; Zou *et al.*, 2023) [1, 12, 15]. Similarly, nano-urea has gained attention as a promising nitrogen source due to its controlled-release properties, improved nutrient uptake, and reduced environmental losses, leading to enhanced crop performance and sustainability (Kumar *et al.*, 2021) [11]. In rainfed rice ecosystems, where nutrient availability and water supply are highly variable, optimizing nitrogen dose and application method is critical for maximizing productivity and profitability. Previous research has highlighted the potential of integrating higher nitrogen levels with advanced delivery techniques such as improve crop

growth and yield attributes (Mumtahina *et al.*, 2024; Benzon *et al.*, 2015) [8, 2]. However, comparative information on the combined effects of nitrogen levels, nano-urea application, and fertilizer deep placement under rainfed transplanted rice conditions is limited, particularly in the Agro-climatic conditions of Assam. Therefore, the present investigation was undertaken to evaluate the effect of different nitrogen doses and application methods, including nano-urea and fertilizer deep placement, on growth, yield, and economic performance of transplanted rice under rainfed conditions. The study aims to identify an efficient and economically viable nitrogen management strategy for sustainable rice production in the region.

2. Materials and Methods

The present investigation was conducted during the *kharif* seasons of 2022 and 2023 under rain-fed conditions at the Instructional-cum-Research (ICR) Farm, Assam Agricultural University, Jorhat, which is situated at 26º71' N latitude, 94º18' E longitudes and at an altitude of 86.6 m above mean sea level. The amount of rainfall received during crop period was 1024.3 mm and 852.7 mm in 2022 and 2023, respectively. The maximum and minimum temperature ranges from 28.4 to 34.9 and 11.6 to 25.6 in 2022 respectively. The maximum and minimum temperature ranges from 24.6 to 36.6 and 12.7 to 25.7 in 2023 respectively. The experiment was laid out in a Randomized Block Design (RBD) with a plot size of 4 m × 3 m. The study consisted of three replications. The treatment combinations are T_1 - Control; T_2 - 50% RDN; T_3 - 75% RDN; T_4 - 100% RDN; T_5 - 125% RDN; T_6 - 50% RDN + Nano-urea; T_7 - 75% RDN + Nano-urea; T_8 - 100% RDN + Nano-urea; T_9 - 125% RDN + Nano-urea; T_{10} - 50% RDN as FDP; T_{11} - 75% RDN as FDP; T_{12} - 100% RDN as FDP and T_{13} - 125% RDN as FDP. (Note: RDN= Recommended dose of Nitrogen; FDP= Fertilizer deep placement).

3. Results and discussion

3.1 Effect on Plant height (cm)

Plant height increased significantly with the application of nitrogen at various growth stages. The treatment with 125% RDN as FDP (T_{13}) achieved significantly higher plant heights of 130.76 cm, 148.31 cm, and 146.26 cm at 60 DAT, 90 DAT, and at harvest, respectively, compared to other treatments. In 30 DAT 125% RDN+ nano-urea (T_9) treatment recorded highest plant height (69.39 cm). However, these results were at par to those from 125% RDN+ nano-urea (T_9) and 100% RDN as FDP (T_{12}). The significant increase in plant height is because nitrogen is a critical nutrient that plays a vital role in plant growth, influencing processes such as photosynthesis, tillering, and overall biomass accumulation (Bandaogo *et al.*, 2015) [1]. The deep placement of nitrogen fertilizers ensures that the nutrients are available in the root zone, promoting better uptake and utilization by the plants (Zou *et al.*, 2023) [15].

3.2. Effect on No of tillers per m^2

Results shows that the application of nitrogen significantly increased the number of tillers/ m² at various growth stages of transplanted rice (TPR). The treatment with 125% RDN as FDP (T_{13}) produced significantly higher tiller counts per m² was 330.16, 347.92, 315.79, and 310.86 at 60, 90 DAT, and at harvest, respectively compared to all other treatments. However, these results were statistically comparable to those from 125% RDN + nano-urea (T_9) and 100% RDN as FDP (T_{12}). Correspondingly lowest number of tillers were recorded in T_1 (Control) treatment. The increase in tiller number observed with the application of 125% RDN as FDP (T_{13}) can be attributed to the efficient delivery of nitrogen to the root zone, promoting better nutrient uptake and utilization by the plants. Optimized nitrogen fertilization strategies, including deep placement and controlled-release fertilizers, improved yield and nitrogen accumulation in rice (Zou *et al*., 2023) [15] and Sekhar *et al*. (2014) [10]. The application of nitrogen fertilizers through deep placement methods led to increased nitrogen recovery efficiency and grain yield in various rice cultivars, reinforcing the positive impact of such practices on tiller development (Wang *et al.*, 2022) [12] .

3.3 Effect on dry weight (g/m^2)

The dry weight of transplanted rice (TPR) increased significantly with the application of nitrogen, particularly when combined with nano urea and Fertilizer Deep Placement methods at different growth stages. The treatment with 125% RDN as FDP (T_{13}) resulted in significantly higher dry weights are 473.94, 1019.65, 1357.88, and 1528.14 g/m² at 30, 60, 90 DAT, and at harvest, respectively compared to all other treatments. However, these results were statistically at par to those from 125% RDN nano-urea (T_9) and 100% RDN as FDP (T_{12}). Fertilizer deep placement method ensures that nutrients are readily available to the plants, leading to improved growth and higher biomass accumulation. Gill *et al*. (2006) [4] and Bandaogo *et al.*, 2015. [1]

3.4 Effect on grain yield

The grain yield data (q/ha) for various nitrogen underscores the effectiveness of different fertilization strategies in transplanting methods of establishment, Treatment T_{13} (125% RDN as FDP) registered the highest pooled grain yield of 53.04 q/ha. It was followed by treatment T_9 (125% RDN + nano-urea), yielding 50.75 q/ha (Table 4.19 and 4.20). This treatment was statistically comparable to T_{13} in the transplanting method. Conversely, the lowest yield was recorded with Treatment T_1 (control), with 21.24 q/ha. FDP significantly increased rice yields compared to traditional methods (Mumtahina *et al*., 2024) [8]. Additionally, FDP led to more grains per panicle and higher panicle density, contributing to greater overall yield (Mankotia *et al.*, 2009) [7]. Deep fertilizer placement enhances nutrient availability directly to plant roots, improving uptake efficiency in transplanted rice (Nagabhushanam and Bhatt, 2020) [9]. This method reduces nutrient loss in the upper soil layers and concentrates nutrients in the root zone, allowing plants to absorb them more effectively and reducing the need for excessive fertilizer applications (Benzon *et al.* 2015) [2]. The improved nutrient assimilation by plants has played a pivotal role in fostering optimal growth of plant components and essential metabolic processes like photosynthesis. Consequently, this phenomenon has facilitated the maximum accumulation and translocation of photosynthates towards the economically valuable plant parts. This effect is in accordance with prior studies by Harsini *et al.* (2014) [5], and Benzon *et al.* (2015) [2].

3.5 Effect on Straw yield (q/ha)

The highest straw yield was recorded with application of 125% RDN as FDP (T_{13}) with average of 68.41 q/ha. This was closely followed by 125% RDN + nano-urea (T_9) yielding 65.71 q/ha, which was statistically at par to T_{13}. The lowest straw yield was seen with treatment T_1 (control), averaging 36.73 q/ha. FDP improves the root zone nutritional environment, allowing for better absorption of nitrogen and other essential nutrients, particularly during critical growth stages between 50-75 days after sowing (DAS) (Sheoran *et al.*, 2025) [11]. Deep placement methods, such as using hand or applicator tools, enhanced nitrogen use efficiency and reduced nitrogen losses. This led to better overall plant growth, including increased straw biomass. Increased nitrogen levels lead to the production of growth-promoting hormones and compounds within the plant, enhancing cell division and elongation, which contributes to increased biomass and higher straw yields (Wu *et al.*, 2017) [13]. The deep placement of fertilizers encourages the development of a more extensive root system. As roots grow deeper to access nutrients, they can also explore a larger volume of soil, which improves the plant overall ability to absorb water and other essential nutrients (Zhu *et al.*, 2019); (Li *et al.*, 2020) [14, 6].

3.6 Effect on Economics

The lowest cost of cultivation was recorded under T_1 (Control) with a mean value of Rs. 44,305.50/ha, owing to the absence of nitrogen fertilizer application the highest cost of cultivation was observed in T_{13} (125% RDN as FDP), which registered a mean cost of Rs. 50,380.58/ha, followed closely by T_{12} (100% RDN as FDP) with Rs. 50,173.63/ha. Overall, treatments involving higher nitrogen doses and fertilizer deep placement (FDP).

The highest gross returns were achieved with treatment T_{13} (125% RDN as FDP), resulting in an average return of ₹146,253.82/ha. Following this, the second highest returns were recorded with Treatment T_9 (125% RDN + nano-urea) at ₹134,683.56 / ha. In stark contrast, the lowest gross returns were observed in the control group treatment T_1 leading to an average return of ₹63,149.74 / ha.

The highest net returns were recorded for Treatment T_{13} (125% RDN as FDP). This treatment yielded an outstanding mean net return of ₹ 95,873.24 /ha over the two years using FDP with 125% RDN significantly enhanced profitability, this was followed by treatment T_9 (125% RDN + nano-urea), with a mean net return of ₹90,624.47 /ha. The lowest net returns were noted for the control treatment T_1 (control), with a mean net return of ₹18,844.24 /ha.

Among the treatments evaluated, the one with the highest mean benefit-cost ratio of 1.90 corresponds to the application of treatment 125% RDN as FDP (T_{12}). The second highest mean ratio of 1.83 is associated with the treatment of 125% RDN + nano-urea. The lowest mean benefit-cost ratio of 0.43 is linked to the control treatment (T_1) with no additional nitrogen application.

Table 1: Effect of nano-urea and fertilizer deep placement on plant height of transplanted *kharif* rice

Treatment	Plant height (cm)											
	30 DAT			60 DAT			90 DAT			At harvest		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1 - Control	48.94	47.84	48.39	82.64	80.24	81.44	90.52	87.62	89.07	89.52	88.02	88.77
T_2- 50% RDN	52.22	53.02	52.62	91.83	93.23	92.53	101.83	103.93	102.88	100.73	101.53	101.13
T_3- 75% RDN	54.72	55.62	55.17	95.42	102.65	99.04	105.38	115.45	110.42	104.86	112.95	108.91
T_4- 100% RDN	54.54	55.64	55.09	103.42	105.92	104.67	115.42	118.82	117.12	114.37	116.17	115.27
T_5- 125% RDN	59.51	60.71	60.11	111.68	115.91	113.80	126.7	134.58	130.64	127.83	131.72	129.78
T_6- 50% RDN + Nano-urea	49.92	50.52	50.22	98.52	94.55	96.54	108.85	107.88	108.37	107.7	105.96	106.83
T_7- 75% RDN + Nano-urea	62.44	64.14	63.29	104.6	107.4	106.00	118.64	122.24	120.44	118.25	120.35	119.30
T_8- 100% RDN + Nano-urea	65.47	67.77	66.62	112.41	114.98	113.70	130.08	131.00	130.54	128.92	130.33	129.63
T_9- 125% RDN + Nano-urea	68.14	70.64	69.39	121.56	125.76	123.66	141.56	146.86	144.21	140.76	144.16	142.46
T_{10}- 50% RDN as FDP	56.88	58.41	57.65	100.35	100.62	100.49	112.35	111.65	112.00	111.35	109.1	110.23
T_{11}- 75% RDN as FDP	59.67	61.07	60.37	107.73	110.83	109.28	124.89	128.79	126.84	125.99	128.29	127.14
T_{12}- 100% RDN as FDP	62.86	64.76	63.81	113.99	116.46	115.23	131.11	135.91	133.51	129.17	132.03	130.60
T_{13}- 125% RDN as FDP	64.31	66.41	65.36	128.51	133.01	130.76	145.51	151.11	148.31	143.85	148.67	146.26
SEm (±)	1.67	1.68	-	4.9	5.51	-	4.87	5.53	-	4.95	5.17	-
CD (P=0.05)	4.89	4.9	-	14.32	16.1	-	14.21	16.14	-	14.45	15.1	-

Table2: Effect of nano-urea and fertilizer deep placement on number of tillers of transplanted *kharif* rice

Treatment	Number of tillers/m^2											
	30 DAT			60 DAT			90 DAT			At harvest		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1 - Control	208.62	205.22	206.92	220.62	218.12	219.37	202.06	200.36	201.21	197.94	196.74	197.34
T_2- 50% RDN	218.88	225.38	222.13	232.74	236.24	234.49	211.81	213.31	212.56	210.73	211.63	211.18
T_3- 75% RDN	249.87	257.87	253.87	265.34	270.34	267.84	241.67	244.17	242.92	239.97	241.37	240.67
T_4- 100% RDN	262.40	263.10	262.75	279.53	276.97	278.25	245.45	248.15	246.80	242.85	244.35	243.60
T_5- 125% RDN	281.20	291.70	286.45	301.20	308.70	304.95	270.94	275.44	273.19	267.60	270.10	268.85
T_6- 50% RDN + Nano-urea	229.09	236.09	232.59	243.41	247.41	245.41	221.86	223.66	222.76	220.63	221.73	221.18
T_7- 75% RDN + Nano-urea	254.60	271.40	263.00	271.47	285.53	278.50	253.19	256.19	254.69	250.52	252.32	251.42
T_8- 100% RDN + Nano-urea	274.30	284.30	279.30	292.54	299.54	296.04	264.07	274.73	269.40	261.16	263.46	262.31
T_9- 125% RDN + Nano-urea	302.76	314.76	308.76	321.43	329.93	325.68	291.76	297.26	294.51	288.64	291.84	290.24
T_{10}- 50% RDN as FDP	239.31	246.81	243.06	254.87	259.37	257.12	231.18	233.38	232.28	229.35	230.65	230.00
T_{11}- 75% RDN as FDP	271.37	280.87	276.12	288.37	294.87	291.62	261.83	265.33	263.58	259.33	261.43	260.38
T_{12}- 100% RDN as FDP	286.07	296.07	291.07	305.61	313.61	309.61	275.40	280.40	277.90	271.42	274.32	272.87
T_{13}- 125% RDN as FDP	323.66	336.66	330.16	343.42	352.42	347.92	312.79	318.79	315.79	309.11	312.61	310.86
SEm (±)	11.97	13.59	-	12.66	13.20	-	11.94	13.12	-	11.58	12.03	-
CD (P=0.05)	34.96	39.69	-	36.95	38.53	-	34.85	38.31	-	33.81	35.13	-

Table 3: Effect of nano-urea and fertilizer deep placement on dry weight of transplanted *kharif* rice

Treatment	Dry weight (g/m^2)											
	30 DAT			60 DAT			90 DAT			At harvest		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1 - Control	233.56	226.66	230.11	523.56	511.56	517.56	693.19	674.19	683.69	772.83	747.71	760.27
T_2- 50% RDN	274.35	278.55	276.45	592.25	607.55	599.90	798.74	813.61	806.18	881.79	911.81	896.80
T_3- 75% RDN	322.26	333.46	327.86	697.95	722.05	710.00	935.66	966.59	951.13	1039.81	1085.69	1062.75
T_4- 100% RDN	338.12	350.12	344.12	729.85	757.15	743.50	972.84	1010.62	991.73	1081.88	1131.83	1106.86
T_5- 125% RDN	392.56	410.56	401.56	863.45	905.45	884.45	1162.34	1215.68	1189.01	1295.52	1367.59	1331.56
T_6- 50% RDN + Nano-urea	299.54	306.64	303.09	633.15	651.25	642.20	856.94	875.39	866.17	946.38	983.37	964.88
T_7- 75% RDN + Nano-urea	361.02	373.52	367.27	757.75	787.75	772.75	1023.75	1066.78	1045.27	1144.61	1200.84	1172.73
T_8- 100% RDN + Nano-urea	373.01	389.11	381.06	821.55	859.55	840.55	1106.82	1156.68	1131.75	1231.54	1301.84	1266.69
T_9- 125% RDN + Nano-urea	443.11	461.61	452.36	956.25	1008.25	982.25	1269.76	1331.73	1300.75	1416.82	1500.93	1458.88
T_{10}- 50% RDN as FDP	309.49	317.79	313.64	674.05	695.05	684.55	889.82	913.72	901.77	988.28	1030.71	1009.50
T_{11}- 75% RDN as FDP	366.60	381.50	374.05	796.65	828.65	812.65	1057.76	1104.88	1081.32	1180.41	1243.64	1212.03
T_{12}- 100% RDN as FDP	411.50	429.50	420.50	908.35	954.35	931.35	1221.83	1278.84	1250.34	1363.38	1439.75	1401.57
T_{13}- 125% RDN as FDP	463.94	483.94	473.94	992.15	1047.15	1019.65	1325.38	1390.38	1357.88	1483.63	1572.65	1528.14
SEm (±)	18.28	18.03	-	40.3	39.29	-	55.68	56.46	-	63.52	64.73	-
CD (P=0.05)	53.37	52.63	-	117.74	114.69	-	162.32	164.8	-	185.42	188.94	-

Table 4: Effect of nano -urea and fertilizer deep placement on grain yield and straw yield in transplanted *kharif* rice

Treatment	Grain yield (q/ha)			Straw yield (q/ha)		
	2022	2023	Pooled	2022	2023	Pooled
T_1 - Control	22.04	20.44	21.24	37.90	35.56	36.73
T_2- 50% RDN	27.81	28.91	28.36	44.77	46.25	45.51
T_3- 75% RDN	33.39	35.00	34.20	49.75	51.80	50.78
T_4- 100% RDN	36.45	38.07	37.26	52.12	54.05	53.09
T_5- 125% RDN	43.76	45.54	44.65	60.39	62.85	61.62
T_6- 50% RDN + Nano-urea	28.65	30.00	29.33	44.98	46.80	45.89
T_7- 75% RDN + Nano-urea	35.16	36.81	35.99	50.98	53.01	51.99
T_8- 100% RDN + Nano-urea	42.23	43.99	43.11	58.27	60.26	59.27
T_9- 125% RDN + Nano-urea	49.83	51.66	50.75	64.78	66.64	65.71
T_{10}- 50% RDN as FDP	31.81	33.21	32.51	48.67	50.48	49.57
T_{11}- 75% RDN as FDP	39.58	41.29	40.43	56.59	58.63	57.61
T_{12}- 100% RDN as FDP	45.05	46.86	45.96	60.37	62.33	61.35
T_{13}- 125% RDN as FDP	52.09	53.98	53.04	67.72	69.09	68.41
SEm (±)	1.27	1.31	0.36	1.88	1.91	0.53
CD (P=0.05)	3.71	3.82	1.02	5.48	5.58	1.49
Year (Y)			NS			NS
Y*T			NS			NS

Table 5: Effect of nano-urea and fertilizer deep placement on economics of transplanted *kharif* rice

Treatment	Cost of cultivation (Rs / ha)			Gross returns (Rs / ha)			Net returns (Rs / ha)			B-C Ratio		
	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean	2022	2023	Mean
T_1 - Control	43563.00	45048.00	44305.50	63906.33	62393.14	63149.74	20343.33	17345.14	18844.24	0.47	0.39	0.43
T_2 - 50% RDN	48283.14	49858.14	49070.64	79109.97	86228.36	82669.17	30826.82	36370.22	33598.52	0.64	0.73	0.68
T_3 - 75% RDN	48490.10	50065.10	49277.60	92991.15	102305.00	97648.08	44501.05	52239.90	48370.48	0.92	1.04	0.98
T_4 - 100% RDN	48697.13	50272.13	49484.63	100410.57	110126.87	105268.72	51713.44	59854.74	55784.09	1.06	1.19	1.13
T_5 - 125% RDN	48904.08	50479.08	49691.58	119473.90	130846.00	125159.95	70569.82	80366.92	75468.37	1.44	1.59	1.52
T_6 - 50% RDN + Nano-urea	48346.15	49921.15	49133.65	80936.25	88890.00	84913.13	32590.10	38968.85	35779.47	0.67	0.78	0.73
T_7 - 75% RDN + Nano-urea	48449.63	50024.63	49237.13	97217.40	106859.43	102038.42	48767.77	56834.80	52801.29	1.01	1.14	1.07
T_8 - 100% RDN + Nano-urea	48553.14	50128.14	49340.64	115278.80	126153.76	120716.28	66725.66	76025.62	71375.64	1.37	1.52	1.45
T_9 - 125% RDN + Nano-urea	48656.62	50231.62	49444.12	134042.70	146094.48	140068.59	85386.08	95862.86	90624.47	1.75	1.91	1.83
T_{10} - 50% RDN as FDP	48957.14	50562.14	49759.64	89227.05	97737.03	93482.04	40269.91	47174.89	43722.40	0.82	0.93	0.88
T_{11} - 75% RDN as FDP	49164.10	50769.10	49966.60	109033.72	119442.33	114238.02	59869.62	68673.23	64271.42	1.22	1.35	1.29
T_{12}- 100% RDN as FDP	49371.13	50976.13	50173.63	122094.53	133466.77	127780.65	72723.41	82490.65	77607.03	1.47	1.62	1.55
T_{13}- 125% RDN as FDP	49578.08	51183.08	50380.58	140122.10	152385.54	146253.82	90544.02	101202.46	95873.24	1.83	1.98	1.90

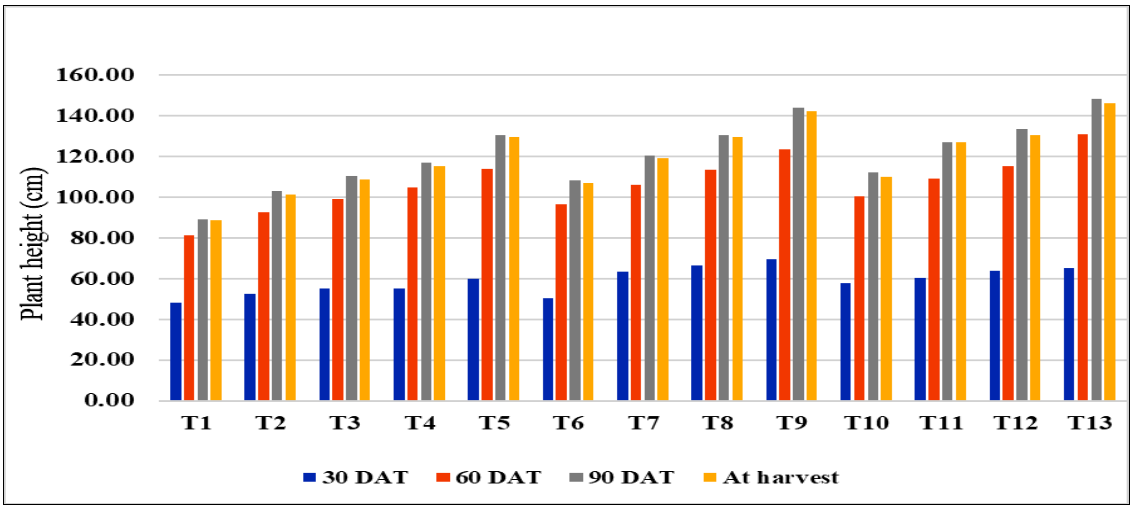

Fig 1: Effect of Nano-Urea and Fertilizer Deep Placement on Plant Height of Transplanted *Kharif* Rice

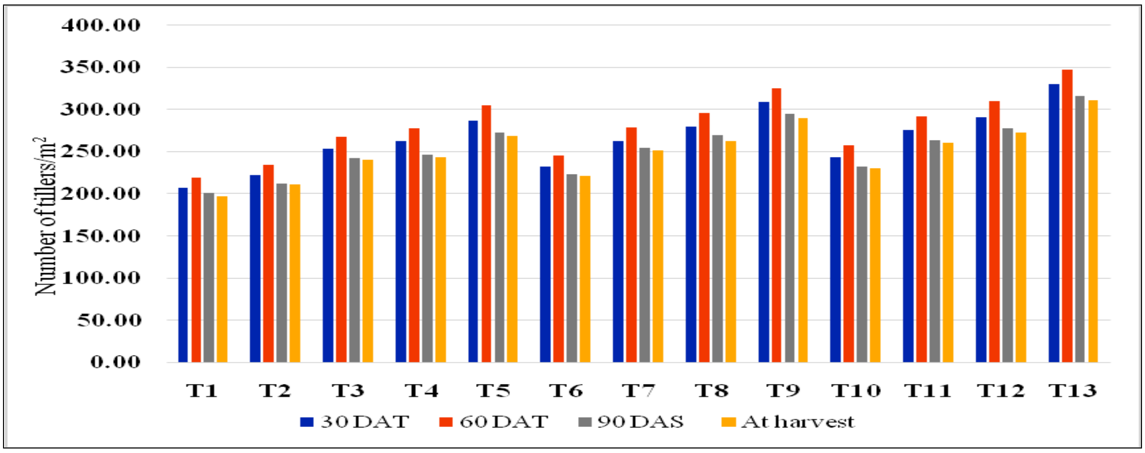

Fig 2: Effect of Nano-Urea and Fertilizer Deep Placement on Number of Tillers of Transplanted *Kharif* Rice

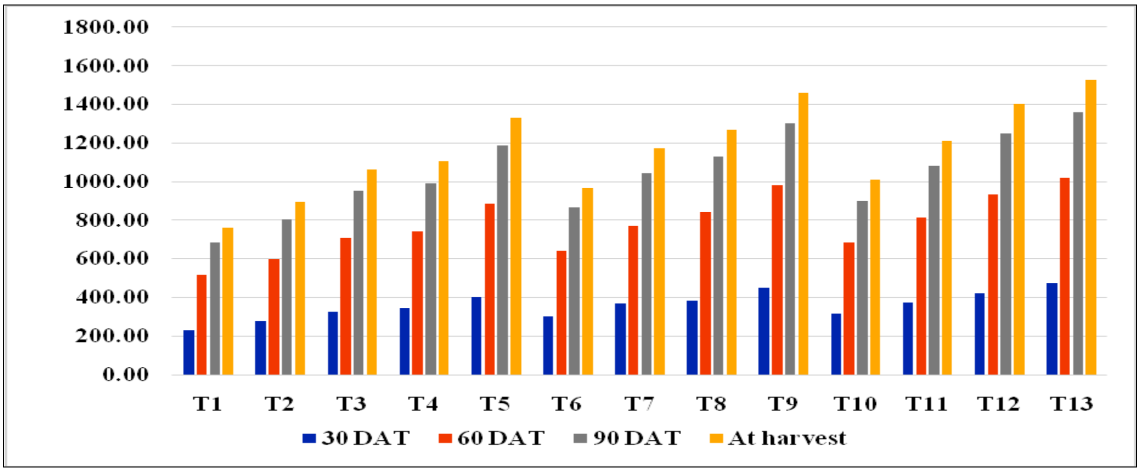

Fig 3: Effect of Nano-Urea and Fertilizer Deep Placement on Dry Weight of Transplanted *Kharif* Rice

Conclusion

The study revealed that nitrogen management significantly influenced the growth, yield, and economics of transplanted rice under rainfed conditions. Among all treatments, 125% RDN applied through fertilizer deep placement (FDP) consistently produced the highest plant height, tiller number, dry matter accumulation, grain yield (53.04 q/ha), and straw yield (68.41 q/ha). Although FDP treatments involved higher cultivation costs, 125% RDN as FDP resulted in the maximum gross and net returns and the highest benefit-cost ratio (1.90), indicating superior profitability. Treatments with 125% RDN + nano-urea and 100% RDN as FDP were statistically comparable with the best treatment for several parameters. Overall, the findings suggest that fertilizer deep placement of nitrogen at 125% RDN is an effective and economically viable nitrogen management strategy for enhancing productivity and profitability of transplanted rice under rainfed conditions.

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