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Effect of super nano urea on growth and yield of hybrid maize

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Abstract
A field experiment entitled "Effect of Super Nano Urea on growth and yield of hybrid maize" was conducted during 2024-2025 at the Research Farm of the Interfaculty Department of Irrigation Water Management, MPKV, Rahuri, Maharashtra, to evaluate the influence of super nano urea (SNU) on hybrid maize performance. The study was laid out in a Randomized Block Design with eleven treatments involving varied proportions of recommended nitrogen doses (RDN) combined with foliar applications of SNU and conventional urea. Results revealed that application of 100% RDF (T_2) significantly enhanced growth attributes, dry matter accumulation (161.31 g plant^{-1}), grain yield (71.88 q ha^{-1}), stover yield (91.47 q ha^{-1}), water productivity (13.31 kg ha^{-1} mm^{-1}), and economic returns (₹173815 ha^{-1} gross and a B:C ratio of 1.80). Treatment T_3 (75% RDN) remained statistically at par with T_2 for major growth and yield parameters. Among reduced-nitrogen treatments, foliar application of SNU at 1.0% twice (T_7: 50% RDN + 2 sprays SNU) recorded notable yield enhancement, with grain and stover yield increases of 30.99% and 35.40%, respectively, over 50% RDN. Nitrogen use efficiency was maximized in T_{11} (25% RDN + three sprays SNU @ 0.50%), achieving 116.40 kg kg^{-1}. Overall, the study demonstrates that while full RDF ensures optimal productivity, integrating SNU foliar sprays with reduced nitrogen levels can substantially improve nitrogen use efficiency, nutrient uptake, and profitability, highlighting the potential of SNU-based nutrient management strategies in hybrid maize.

Keywords: Super nano urea, recommended dose of fertilizer, growth, yield, economics, hybrid maize

Introduction
Maize (*Zea mays* L.) is the world's third most important cereal crop after wheat and rice, valued for its high energy and protein content. Globally, it is grown on about 205 million hectares, producing nearly 1220 million tonnes with an average yield of 5.95 t ha^{-1} (FAO, 2023). India is the fifth-largest producer of maize, cultivating roughly 9.96 million hectares and generating 38.1 million tonnes, though its mean productivity (3580 kg ha^{-1}) remains below the global average (Anonymous, 2024). In the country, maize is grown in both kharif and rabi seasons. The kharif crop, which relies heavily on monsoon rainfall, experiences several abiotic and biotic stresses, resulting in lower yields compared to the irrigated rabi maize (Directorate of Maize Research, 2022).

Limited water supply is one of the most critical constraints on maize production, as it reduces photosynthesis and overall biomass accumulation, which in turn decreases yield (Liu *et al*., 2018) [10]. As per capita water availability continues to fall, the use of water-efficient irrigation techniques-such as drip and sprinkler systems-has become increasingly important for sustaining maize yields (Jain *et al*., 2019; Cetin & Akalp, 2019) [7, 4]. Effective nutrient management, especially of nitrogen, is also crucial for optimum maize growth. Conventional urea has relatively low nitrogen use efficiency (around 30-40%), and considerable nitrogen losses through volatilization and leaching lead to both financial losses and environmental concerns (Yadav *et al*., 2017) [19].

Foliar nutrient application can reduce fertilizer losses and enhance nutrient absorption by the crop. Advances in nanotechnology have introduced nano urea, which-due to its extremely small particle size and greater surface area-promotes better nutrient uptake and improves overall efficiency. An improved version, known as super nano urea, has shown potential for

increasing maize productivity and improving economic returns (Alemayehu & Shewarega, 2015) [1]. Hence, the present investigation was undertaken to assess the effect of foliar application of super nano urea on the yield and economic performance of hybrid maize.

Materials and Methods

The experiment was carried out during the rabi season of 2024-25 at the Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, to assess the yield performance of hybrid maize under foliar application of super nano urea. A Randomized Block Design with eleven treatments and three replications was used. Treatments ranged from control and full RDF to various levels of RDN combined with foliar sprays of super nano urea (SNU) at different concentrations and timings. All treatments except the control received the full recommended P_2O_5 and K_2O doses. The experiment comprised of T_1 - Control (No N:P_2O_5:K_2O), T_2 - Recommended Dose of Fertilizer (GRDF), T_3 - 75% RDN, T_4 - 50% RDN, T_5 - 50% RDN + 2 sprays of SNU @ 0.25% (30 DAS and 50 DAS), T_6 - 50% RDN + 2 sprays of SNU @ 0.50% (30 DAS and 50 DAS), T_7 - 50% RDN + 2 sprays of SNU @ 1.0% (30 DAS and 50 DAS), T_8 - 50% RDN + 2 spray of Conventional Urea @ 1.0% (30 DAS and 50 DAS), T_9 - 50% RDN + 1 spray of SNU @ 1.0% (50 DAS), T_{10} - 50% RDN + 2 sprays of SNU @ 0.50% (50 DAS and 65 DAS), T_{11} - 25% RDN + 3 sprays of SNU @ 0.50% (30 DAS, 50 DAS and 65 DAS). (RDN - Recommended Dose of Nitrogen, RDF - Recommended Dose of Fertilizer, SNU - Super Nano Urea, 100% recommended dose of P_2O_5 and K_2O were applied to all treatments excluding T_1 (control)). Foliar sprays were applied at 30, 50, and 65 DAS as per treatment schedule. Fertilizers used included urea, SSP, MOP, and liquid super nano urea (16% N). The recommended dose for maize was 120:60:40 kg ha^{-1} of N:P_2O_5:K_2O. Super nano urea, with particle sizes below 100 nm, provides nitrogen in multiple forms and improves leaf absorption, chlorophyll formation, and photosynthetic efficiency, thereby enhancing yield potential. Sowing was done on January 6, 2024, using dibbling with 0.60 m × 0.20 m spacing. Crop protection measures were followed as recommended. Growth and yield observations were recorded at different crop stages. Drip irrigation was supplied on alternate days. Soil samples were collected treatment-wise at 30, 60, 90 DAS and harvest from 0-20 cm depth, processed, and analyzed for available N, P, and K. Plant samples taken at harvest were oven-dried, ground, and assessed for total N, P, and K using standard methods. Cost of cultivation was computed by adding operational expenses and irrigation system costs. Gross returns were based on grain and stover yields, and net returns were obtained after deducting total costs. The benefit-cost ratio was calculated by dividing gross returns by total cultivation cost. Statistical analysis was performed using ANOVA for RBD as described by Panse and Sukhatme (1985).

Table 1: Spraying schedule of Super Nano Urea for maize

Tr. No.	NPK (%)	1st Super Nano Urea top dressing (30 DAS)	2nd Super Nano Urea top dressing (50 DAS)	3rd Super Nano Urea top dressing (65 DAS)
T_1	$N_0P_0K_0$	-	-	-
T_2	$N_{100}P_{100}K_{100}$	-	-	-
T_3	$N_{75}P_{100}K_{100}$	-	-	-
T_4	$N_{50}P_{100}K_{100}$	-	-	-
T_5	$N_{50}P_{100}K_{100}$	First spray of SNU @ 0.25%	Second spray of SNU @ 0.25%	-
T_6	$N_{50}P_{100}K_{100}$	First spray of SNU @ 0.5%	Second spray of SNU @ 0.5%	-
T_7	$N_{50}P_{100}K_{100}$	First spray of SNU @ 1.0%	Second spray of SNU @ 1.0%	-
T_8	$N_{50}P_{100}K_{100}$	First spray of conventional urea @ 1.0%	Second spray of conventional urea @ 1.0%	-
T_9	$N_{50}P_{100}K_{100}$	-	First spray of SNU @ 1.0%	-
T_{10}	$N_{50}P_{100}K_{100}$	-	First spray of SNU @ 0.5%	Second spray of SNU @ 0.5%
T_{11}	$N_{25}P_{100}K_{100}$	First spray of SNU @ 0.5%	Second spray of SNU @ 0.5%	Third spray of SNU @ 0.5%

Results and Discussion

Growth Parameters

Plant Height

Maize plant height measured at 30, 60, 90 DAS and at harvest averaged 36.44, 140.04, 224.27 and 225.32 cm, respectively (Table 2). T_2 (100% RDF) recorded the maximum height at 60, 90 DAS and harvest (152.66, 242.74 and 242.80 cm), and was statistically at par with T_3 (75% RDN). The lowest height (130.58, 196.17 and 196.23 cm) occurred in the unfertilized control. The enhanced growth in T_2 and T_3 is attributed to improved nutrient delivery and controlled release from nano-fertilizers. These results align with findings by Veeresh *et al.* (2024) [18] and others, who similarly reported higher plant height with 100% RDN and nano-urea applications compared to reduced or no nitrogen.

Number of Leaves $Plant^{-1}$

The number of leaves per plant recorded at 30, 60, 90 DAS and at harvest averaged 6.61, 11.36, 13.26 and 13.12, respectively (Table 2). T_2 (100% RDF) produced the highest number of leaves at 60, 90 DAS and at harvest (14.98, 18.10 and 17.58), and was statistically at par with T_3 (75% RDN), which recorded 14.60, 17.70 and 16.65 leaves at the corresponding stages. The lowest leaf count (6.20, 9.89 and 9.27) occurred in the unfertilized control. Leaf number increased progressively up to 90 DAS and slightly declined thereafter. The superior performance of T_2 is attributed to improved nutrient availability from the recommended fertilizer dose. These results agree with Sharma *et al.* (2023) [17], who also observed maximum leaf production under 100% RDF.

Stem Girth

Average stem girth recorded at 30, 60, 90 DAS and at harvest was 4.52, 5.32, 6.15 and 7.19 cm, respectively (Table 2). T_2 (100% RDF) produced the maximum stem girth at 60, 90 DAS and at harvest (6.45, 7.34 and 8.10 cm), and was statistically at par with T_3 (75% RDN), which recorded 6.10, 6.95 and 7.74 cm at the same stages. The lowest values (4.69, 5.30 and 6.74 cm) were observed in the unfertilized control. Stem girth increased steadily with crop age, attaining its peak at harvest. The superior stem girth

under T_2 is attributed to improved nutrient availability through the recommended fertilizer dose. These findings align with Veeresh *et al*. (2024) [18], who reported enhanced growth parameters with 100% RDN, with 75% RDN performing similarly.

Yield Contributing Characters

Table. 3 presents the mean values for cobs per plant, grains per plant, grain weight per cob, 100-grain weight (g), cob length (cm), cob girth (cm), and the weight of the outer sheath (g). The number of cobs per plant did not differ significantly across treatments. Among the treatments, T_2 (RDF) recorded the highest values for most yield attributes, including grains per cob (644), grain weight per cob (298 g), 100-grain weight (41.67 g), cob length (28.96 cm), cob girth (15.23 cm), and outer sheath weight (56.35 g). These were closely followed by T_3 (75% RDN), which produced 631 grains per cob, 293 g grain weight per cob, a 100-grain weight of 39.57 g, cob length of 27.69 cm, cob girth of 14.31 cm, and an outer sheath weight of 51.77 g. In contrast, the lowest values for all measured traits were observed in T_1 (Control), where no $N:P_2O_5:K_2O$ fertilizers were applied. Similar trends were also reported by Navya *et al*. (2021) [11].

Table 2: Growth parameters of maize as influenced by foliar application of super nano urea

Tr. No.	Treatments	Plant Height at harvest (cm)	Number of Leaves Plant^{-1} at harvest	Stem girth at harvest (cm)
T_1	Control (No $N:P_2O_5:K_2O$)	196.23	9.27	6.74
T_2	Recommended Dose of Fertilizer (GRDF)	242.80	17.58	8.10
T_3	75% RDN	241.10	16.65	7.74
T_4	50% RDN	218.22	11.24	6.97
T_5	50% RDN + 2 sprays of SNU @ 0.25% (30 DAS and 50 DAS)	219.11	12.01	7.01
T_6	50% RDN + 2 sprays of SNU @ 0.50% (30 DAS and 50 DAS)	224.87	12.36	7.09
T_7	50% RDN + 2 sprays of SNU @ 1.0% (30 DAS and 50 DAS)	230.36	14.87	7.19
T_8	50% RDN + 2 spray of Conventional Urea @ 1.0% (30 DAS and 50 DAS)	228.98	14.09	7.13
T_9	50% RDN + 1 spray of SNU @ 1.0% (50 DAS)	227.59	12.78	7.10
T_{10}	50% RDN + 2 sprays of SNU @ 0.50% (50 DAS and 65 DAS)	223.99	12.35	7.05
T_{11}	25% RDN + 3 sprays of SNU @ 0.50% (30 DAS, 50 DAS and 65 DAS)	214.49	11.09	6.92
	S.E.(m) ±	1.41	0.71	0.21
	C.D at 5%	4.09	2.33	0.59
	General mean	225.32	13.12	7.19

Table 3: Yield contributing characters of maize as influenced by foliar application of super nano urea

Tr. No.	Treatments	Number of cobs per plant	Average Number of grains cob^{-1}	Weight of grains cob^{-1} (g)	100 grains weight (g)	Average Length of cob (cm)	Average Girth of cob (cm)	Weight of outer sheath of cob (g)
T_1	Control (No $N:P_2O_5:K_2O$)	1.07	355	109	26.57	19.23	11.09	19.19
T_2	Recommended Dose of Fertilizer (GRDF)	1.31	644	298	41.67	28.96	15.23	56.35
T_3	75% RDN	1.20	631	293	39.57	27.69	14.31	51.77
T_4	50% RDN	1.10	433	145	30.47	21.62	11.95	24.00
T_5	50% RDN + 2 sprays of SNU @ 0.25% (30 DAS and 50 DAS)	1.16	480	164	31.60	21.93	11.96	25.34
T_6	50% RDN + 2 sprays of SNU @ 0.50% (30 DAS and 50 DAS)	1.18	529	184	32.87	22.33	12.21	33.81
T_7	50% RDN + 2 sprays of SNU @ 1.0% (30 DAS and 50 DAS)	1.26	611	232	36.98	25.98	13.97	42.21
T_8	50% RDN + 2 spray of Conventional Urea @ 1.0% (30 DAS and 50 DAS)	1.12	601	223	35.08	25.16	13.27	40.32
T_9	50% RDN + 1 spray of SNU @ 1.0% (50 DAS)	1.17	576	194	33.24	23.63	13.91	35.09
T_{10}	50% RDN + 2 sprays of SNU @ 0.50% (50 DAS and 65 DAS)	1.13	504	183	32.80	22.14	12.06	28.91
T_{11}	25% RDN + 3 sprays of SNU @ 0.50% (30 DAS, 50 DAS and 65 DAS)	1.09	395	128	30.78	20.19	11.73	20.30
	S.E.(m) ±	0.04	7.01	2.79	1.29	0.85	0.31	2.12
	C.D at 5%	N.S	20.27	8.33	3.98	2.47	1.01	6.36
	General mean	1.16	523.55	195.73	33.78	23.53	10.58	34.30

Yield

Table 3 presents the data on grain yield (q ha^{-1}), stover yield (q ha^{-1}), and the percent increase in these yields under different super nano urea treatments. Significant variations in maize grain and stover yields were observed across the nitrogen management treatments. The maximum grain yield (71.88 q ha^{-1}) and stover yield (91.47 q ha^{-1}) were obtained with the 100% RDF treatment (T_2). These values were statistically comparable to those of T_3 (75% RDN), which produced 69.27 q ha^{-1} of grain and 88.97 q ha^{-1} of stover. Among the 50% RDN treatments, the application of SNU at 1.0% at 30 and 50 DAS (T_7) resulted in higher grain (65.98 q ha^{-1}) and stover yields (86.44 q ha^{-1}) than the foliar spray of conventional urea (T_8), though the difference between the

two was not statistically significant. The control treatment (T_1) recorded the lowest yields, with 39.41 q ha^{-1} of grain and 51.33 q ha^{-1} of stover. The improvements in yield with nano urea application may be due to enhanced absorption through foliage, controlled nutrient release, and increased nutrient use efficiency. The highest percentage increase in grain yield (30.99%) and stover yield (35.40%) was observed in T_7 [50% RDN + two sprays of SNU @ 1.0% at 30 and 50 DAS], followed by T_8, which recorded increases of 29.58% and 34.35%, respectively, over T_3 (50% RDN). The superior performance of nano fertilizers can be linked to better nutrient utilization and improved productivity through foliar nutrient delivery. These findings are consistent with the results reported by Nirere *et al.* (2019) [12], Samui *et al.* (2022) [15], Kalyana Murthy *et al.* (2024) [8], Kumar *et al.* (2024) [9], and Veeresh *et al.* (2024) [18].

Table 3: Yield of maize as influenced by foliar application of super nano urea

Tr. No.	Treatments	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Increase in the grain yield over T_4 (%)	Increase in the stover yield over T_4 (%)
T_1	Control (No N:P_2O_5:K_2O)	39.41	51.33	-	-
T_2	Recommended Dose of Fertilizer (GRDF)	71.88	91.47	-	-
T_3	75% RDN	69.27	88.97	-	-
T_4	50% RDN	50.37	63.84	-	
T_5	50% RDN + 2 sprays of SNU @ 0.25% (30 DAS and 50 DAS)	54.72	68.77	8.64	7.72
T_6	50% RDN + 2 sprays of SNU @ 0.50% (30 DAS and 50 DAS)	56.87	71.49	12.90	11.98
T_7	50% RDN + 2 sprays of SNU @ 1.0% (30 DAS and 50 DAS)	65.98	86.44	30.99	35.40
T_8	50% RDN + 2 spray of Conventional Urea @ 1.0% (30 DAS and 50 DAS)	65.27	85.77	29.58	34.35
T_9	50% RDN + 1 spray of SNU @ 1.0% (50 DAS)	61.27	79.76	21.64	24.94
T_{10}	50% RDN + 2 sprays of SNU @ 0.50% (50 DAS and 65 DAS)	55.39	69.24	9.97	8.46
T_{11}	25% RDN + 3 sprays of SNU @ 0.50% (30 DAS, 50 DAS and 65 DAS)	47.97	60.88	-4.76	-4.64
	S.E.(m) ±	1.24	1.26	-	-
	C.D at 5%	3.48	3.11	-	-
	General mean	58.04	74.36	15.56	16.89

Economic Analysis

Table 4 presents the seasonal cultivation cost (₹ ha^{-1}), net seasonal income (₹ ha^{-1}), benefit-cost (B:C) ratio, and additional income over the control under different foliar applications of super nano urea.

Cost of Cultivation

The cost of cultivating maize differed notably among treatments depending on fertilizer use and foliar application of super nano urea. The maximum expenditure (₹ 99,320 ha^{-1}) was incurred in T_7 (50% RDN + two sprays of SNU @ 1.0% at 30 and 50 DAS), followed closely by T_{11} (25% RDN + three sprays of SNU @ 0.5% at 30, 50, and 65 DAS) with ₹ 98,249 ha^{-1}. The minimum cost (₹ 73,265 ha^{-1}) occurred in the control plot (T_1), where no fertilizers or foliar sprays were applied, resulting in the lowest input requirements.

Gross Monetary Returns

Fertilizer levels and super nano urea applications significantly influenced gross monetary returns. The highest GMR (₹ 1,73,815 ha^{-1}) was obtained from T_2 (100% RDF), which was statistically similar to T_3 (75% RDN), recording ₹ 1,67,709 ha^{-1}. The lowest gross return (₹ 95,593 ha^{-1}) was observed in T_1 (control), attributed to reduced productivity due to the absence of nutrient inputs.

Net Monetary Returns

Net returns followed a trend similar to GMR. The maximum net return (₹ 77,304 ha^{-1}) was achieved in T_2 (100% RDF), with T_3 (75% RDN) also performing similarly, yielding ₹ 71,680 ha^{-1}. The minimum net return (₹ 17,708 ha^{-1}) was recorded in T_{11} (25% RDN + three sprays of SNU @ 0.5% at 30, 50, and 65 DAS). These findings align with the observations of Rajesh *et al.* (2021) [14].

Benefit-Cost Ratio: B:C ratio greater than 1.0 indicates economic viability, while a ratio below 1.0 suggests a loss. The B:C ratio improved with different foliar applications of super nano urea. The highest ratio (1.80) occurred in T_2 (100% RDF), followed by T_3 (75% RDN) with 1.75. The lowest B:C ratio (1.18) was recorded in T_{11}. These results correspond well with the findings of Nirere *et al.* (2019) [12] and Sankar *et al.* (2020) [16].

Table 4: Economics of maize as influenced by foliar application of super nano urea

Tr. No.	Treatments	Gross Monetary Returns (₹ ha$^{-1)}$	Cost of Cultivation (₹ ha^{-1})	Net Monetary Returns (₹ ha^{-1})	B:C ratio
T_1	Control (No N:P_2O_5:K_2O)	95593	73265	22328	1.30
T_2	Recommended Dose of Fertilizer (GRDF)	173815	96511	77304	1.80
T_3	75% RDN	167709	96029	71680	1.75
T_4	50% RDN	121737	93426	28311	1.30
T_5	50% RDN + 2 sprays of SNU @ 0.25% (30 DAS and 50 DAS)	132104	97571	34533	1.35
T_6	50% RDN + 2 sprays of SNU @ 0.50% (30 DAS and 50 DAS)	137299	98154	39145	1.40
T_7	50% RDN + 2 sprays of SNU @ 1.0% (30 DAS and 50 DAS)	160168	99320	60848	1.61
T_8	50% RDN + 2 spray of Conventional Urea @ 1.0% (30 DAS and 50 DAS)	158509	97062	61447	1.63
T_9	50% RDN + 1 spray of SNU @ 1.0% (50 DAS)	148607	96712	51895	1.54
T_{10}	50% RDN + 2 sprays of SNU @ 0.50% (50 DAS and 65 DAS)	133629	98154	35475	1.36
T_{11}	25% RDN + 3 sprays of SNU @ 0.50% (30 DAS, 50 DAS and 65 DAS)	115957	98249	17708	1.18
	S.E.(m) ±	3349	-	3349	-
	C.D at 5%	10048	-	10048	-
	General mean	140466	-	45516	-

Conclusion

Results showed that maize growth parameters-plant height, number of leaves plant^{-1}, and stem girth-were significantly improved by nutrient management treatments. T_2 (100% RDF) recorded the highest growth across stages, followed closely by T_3 (75% RDN), indicating comparable effectiveness. Treatments combining 50% RDN with super nano urea also enhanced growth over conventional urea. The lowest values occurred in the unfertilized control, confirming the necessity of adequate nutrient supply. Overall, the study demonstrates that recommended fertilization and nano-urea-based approaches effectively promote maize growth and offer a promising strategy for efficient nutrient management. Maize yield attributes were significantly improved by nutrient treatments. T_2 (100% RDF) produced the highest number of grains cob^{-1}, cob length, cob girth, 100-grain weight, total cob weight, and sheath weight, with T_3 (75% RDN) performing statistically at par. The lowest values for all traits were recorded in the unfertilized control (T_1). Grain and stover yields increased with higher fertilizer doses and super nano urea application. T_2 achieved the maximum grain (71.88 q ha^{-1}) and stover yield (91.47 q ha^{-1}), followed closely by T_3. Among 50% RDN treatments, T_7 (50% RDN + SNU @1.0%) recorded the highest grain and stover yields and the greatest percentage increases over reduced-dose treatments, outperforming conventional urea sprays. The minimum yields were obtained in the control (T_1).

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