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Effect of foliar application of nano-urea on growth, yield and quality attributes in tomato (*Solanum lycopersicum* L.)

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ABSTRACT

Climate change, increasing fertilizer costs and concerns regarding environmental sustainability have intensified the need for efficient nitrogen management in vegetable production. In this context, nano-fertilizers have emerged as a promising approach to enhance nutrient use efficiency and reduce nutrient losses. A field experiment was conducted during the Rabi season of 2025-26 at the Horticultural Research cum Instructional Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh), to evaluate the effect of foliar application of nano-urea on the growth, yield, quality and economics of tomato (*Solanum lycopersicum* L.) cv. Kashi Aman. The experiment comprised ten treatments and three replications in a randomized block design, involving combinations of three nitrogen levels (100, 75 and 50% recommended dose of nitrogen, RDN) with zero, one or two foliar sprays of nano-urea (4 mL L⁻¹) applied at 30 and 50 days after transplanting (DAT), along with an absolute no-nitrogen control. Among the treatments, 100 % RDN supplemented with two foliar sprays of nano-urea (T₃) recorded significantly superior growth and yield attributes, including maximum plant height at harvest (85.48 cm), earliest flowering (33.05 days), highest number of fruits per plant (41.26), fruit equatorial diameter (5.64 cm), fruit polar diameter (4.67 cm) and fruit yield (548.67 q ha⁻¹). Fruit quality parameters such as total soluble solids, ascorbic acid content, titratable acidity and firmness were not significantly influenced by the treatments. Economic analysis revealed that T₃ generated the highest net return (₹3,62,016.45 ha⁻¹) and benefit-cost ratio (2.94). The results indicate that foliar application of nano-urea, when integrated with an adequate basal nitrogen supply, enhances tomato growth, productivity and profitability without adversely affecting fruit quality. Therefore, nano-urea may serve as an effective supplementary nitrogen source for improving nitrogen use efficiency and supporting sustainable tomato production under changing climatic conditions and increasing fertilizer-use constraints.

Keywords: Nano-urea, Tomato, Foliar application, Yield attributes, Benefit-cost ratio

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Introduction

Tomato (*Solanum lycopersicum* L.), family Solanaceae, is a dicotyledonous, self-pollinated, warm-season vegetable crop (2n = 24) that originated in South America and now ranks second among the world's vegetable crops after potato in area and production. India is the second-largest producer of tomato after China, with a cultivated area of about 834 thousand hectares and an annual production of around 21,461 thousand tonnes; Chhattisgarh alone contributes about 857.98 thousand tonnes from roughly 49.11 thousand hectares (Department of Agriculture & Farmers Welfare, 2026) [1]. Tomato is valued both for fresh consumption and for a wide range of processed products and its fruit is a rich source of water, minerals, vitamins A and C, B-complex vitamins and antioxidants such as lycopene (Mukesh et al., 2023) [2].

Meeting the growing demand for tomato depends heavily on efficient fertilizer management, since crop productivity is strongly linked to adequate nutrient supply (Roberts, 2009) [3]. Among the macronutrients, nitrogen is central to chlorophyll, protein, enzyme and nucleic acid synthesis and it drives vegetative growth and photosynthetic capacity; both its deficiency and its excess are detrimental to fruit yield and quality. Conventional soil-applied urea, however, suffers from low nitrogen-use efficiency owing to losses through leaching, volatilization and denitrification, which raises production costs and contributes to environmental pollution. Optimizing nitrogen use while sustaining yield is therefore central to economically and environmentally sound tomato production.

Nanotechnology has opened a new avenue for improving nutrient-use efficiency through nano-fertilizers, characterized by extremely small particle size (1–100 nm), a very high surface-area-to-volume ratio and enhanced reactivity that together improve nutrient absorption and utilization (Mahil et al., 2019) [4]. Nano-urea, developed and commercialized by the Indian Farmers Fertiliser Cooperative Limited (IFFCO), con

tains about 4 % nitrogen in nanoparticulate form (20–50 nm) in a 500 mL bottle. Due of their small size, nano-urea particles penetrate leaf tissue through stomata and cuticular pathways during foliar application and are subsequently translocated through the phloem to sink organs such as fruits, giving more targeted nutrient delivery than soil-applied urea (Suthar *et al.*, 2023) [5].

Field studies on tomato report that combining a basal nitrogen dose with foliar sprays of nano-urea improves vegetative growth, hastens flowering and fruiting and increases fruit size and total yield over conventional fertilization alone (Panda *et al.*, 2020a, Panda *et al.*, 2020b; Mishra *et al.*, 2020; Malica *et al.*, 2024; Kumar *et al.*, 2025) [6, 7, 8, 9], although fruit-quality traits respond less consistently and depend on cultivar, nitrogen level and spray schedule (Helal *et al.*, 2023) [10].

Materials and methods

The experiment was conducted during the *Rabi* season of 2025-26 at the Horticultural Research cum Instructional Farm, Department of Vegetable Science, College of Agriculture, IGKV, Raipur, Chhattisgarh to evaluate the effect of foliar application of nano-urea on growth, yield and quality attributes in tomato (*Solanum lycopersicum* L.). The experiment was laid out in a randomized block design (RBD) with three replications. Ten treatments viz., 100 % RDN + foliar spray with water (control) (T_1), 100 % RDN + one spray of nano urea @ 4 ml/litre at 30 DAT (T_2), 100 % RDN + two sprays of nano urea @ 4 ml/litre at 30 and 50 DAT (T_3), 75 % RDN + foliar spray with water (T_4), 75 % RDN + one spray of nano urea @ 4 ml/litre at 30 DAT (T_5), 75 % RDN + two sprays of nano urea @ 4 ml/litre at 30 and 50 DAT (T_6), 50 % RDN + foliar spray with water (T_7), 50 % RDN + one spray of nano urea @ 4 ml/litre at 30 DAT (T_8) and 50 % RDN + two sprays of nano urea @ 4 ml/litre at 30 and 50 DAT (T_9) were tested against no nitrogen (T_{10}). Tomato variety Kashi Aman' was used in the experiment. The soil of the experimental field was clay loam (dorsa) with medium organic carbon (0.60%), low available N (275.0 kg ha⁻¹), medium available P (16.75 kg ha⁻¹), high available K (303.0 kg ha⁻¹) and near-neutral pH (7.09). They were trans-

planted on 5 December 2025 at 60 cm × 45 cm spacing in 2 m × 2 m plots. Standard cultural practices were applied uniformly across all plots. In each plot, the five plants were selected randomly and tagged for the purposes of observations and recorded observations were analysed.

Results and discussion

Perusal of data showed that plant height did not differ significantly among treatments up to 45 DAT, but differences became significant from 90 DAT onward (Table 2). At harvest, T_3 recorded the tallest plants (85.48 cm), significantly taller than all other treatments, while T_{10} (no nitrogen) remained the shortest (72.73 cm). The sustained height advantage of T_3 suggests that supplementing full RDN with two foliar nano-urea sprays-maintained nitrogen availability through the active vegetative phase more effectively than soil application alone; since nitrogen is a structural component of chlorophyll and protein, its continued supply supports vegetative growth (Mahantesh *et al.*, 2023) [11].

Primary branches ranged from 3.80 (T_{10}) to 4.37 (T_3) and did not differ significantly, whereas secondary branch number, leaf area and all flowering/early-fruited traits varied significantly. T_3 recorded the maximum secondary branches (11.72), flowered earliest (33.05 days to first flowering; 40.44 days to 50% flowering), produced the most flowers (4.48) and fruits (4.09) cluster⁻¹ and reached first fruit set fastest (41.48 days); T_{10} was consistently the slowest. Notably, T_5 (75 % RDN + one spray) performed close to full-RDN treatments for flowers per cluster, indicating that even a single spray can partly compensate for reduced basal nitrogen.

Fruit number, fruit size, fruit weight and yield all differed significantly among treatments (Table 3). T_3 bore the maximum fruits plant⁻¹ (41.26), followed by T_2 (39.44) and T_1 (37.74), while T_{10} bore the fewest (31.40). T_3 also reached first picking earliest (69.00 days) and produced the largest fruits at the second picking, with maximum equatorial diameter (5.64 cm), polar diameter (4.67 cm) and average fruit weight (39.17 g).

Table 2. Effect of foliar application of nano-urea on growth and flowering attributes of tomato

Treatment	Plant height (cm)	Primary branches	Secondary branches	Leaf area (cm ²)	Days to 1st flowering	Days to 50% flowering	Flowers cluster ⁻¹	Fruits cluster ⁻¹
T_1	82.15	4.10	10.94	458.89	35.17	43.21	4.15	3.82
T_2	82.39	4.26	11.15	455.15	34.32	42.02	4.30	3.89
T_3	85.48	4.37	11.72	459.12	33.05	40.44	4.48	4.09
T_4	77.09	4.09	9.50	452.46	38.67	46.23	3.86	2.82
T_5	80.37	4.13	10.42	454.39	36.22	45.87	4.08	3.69
T_6	81.76	4.23	10.82	446.89	36.45	45.52	3.84	3.75
T_7	74.48	4.03	9.32	443.34	40.26	46.69	3.75	3.21
T_8	79.86	4.17	10.40	449.38	36.94	44.11	3.81	3.11
T_9	81.60	4.14	11.02	438.51	36.56	44.72	3.90	3.13
T_{10}	72.73	3.80	9.03	429.55	41.50	49.07	3.28	2.24
SEm±	0.86	0.18	0.55	32.54	0.74	0.62	0.15	0.17
CD (5%)	2.56	NS	1.64	NS	2.20	1.85	0.45	0.50
CV (%)	9.86	7.31	9.20	12.50	11.42	12.37	8.62	8.67

Note: NS = non-significant at $P = 0.05$; values are means of three replications.

Yield plot⁻¹ and yield hectare⁻¹ followed the trend of their component traits. On a hectare basis, T_3 produced the maximum yield (548.67 q ha⁻¹), followed by T_2 (538.25 q ha⁻¹) and T_1 (518.17 q ha⁻¹), while T_{10} recorded the lowest yield (300.83 q ha⁻¹) (Fig. 1). Within each RDN level, two nano-urea sprays consistently outyielded one spray, which in turn outyielded the water-sprayed check (

$T_3 > T_2 > T_1$; $T_6 > T_5 > T_4$; $T_9 > T_8 > T_7$). Importantly, T_5 and T_6 (75% RDN with one or two sprays) yielded significantly more than T_4 (75% RDN, water spray) and remained statistically at par with several full-RDN treatments, indicating that foliar nano-urea can partly offset a reduction in basal nitrogen dose without a proportionate yield penalty.

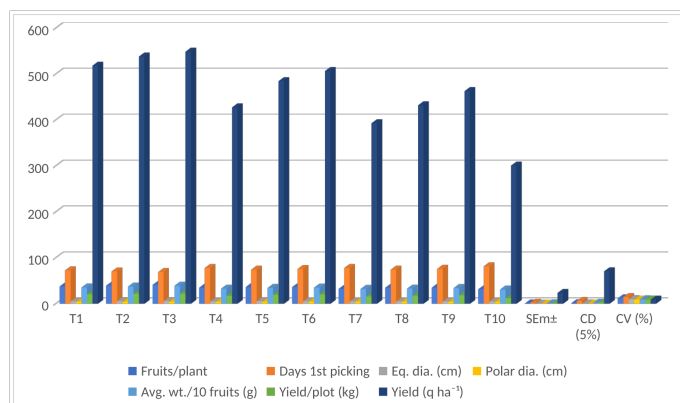


Figure 1. Fruit yield (q ha^{-1}) of tomato as influenced by RDN levels and foliar nano-urea

Unlike growth and yield traits, none of the quality parameters – TSS, ascorbic acid, titratable acidity and fruit firmness – differed significantly among treatments (Table 4). TSS ranged from 3.27°Brix (T_4 , T_{10}) to 3.50°Brix (T_2); ascorbic acid ranged from $16.02 \text{ mg } 100 \text{ g}^{-1}$ (T_7) to $17.68 \text{ mg } 100 \text{ g}^{-1}$ (T_3); titratable acidity ranged from 0.24% (T_5) to 0.29% (T_3); and firmness ranged from 0.50 (T_{10}) to 0.59 (T_3). Although statistically non-significant, all four traits showed a consistent numerical advantage in the nano-urea-sprayed, full-RDN treatments over the water-sprayed and no-nitrogen treatments. This is broadly consistent with Kumar *et al.* (2025) [12], who reported significantly higher TSS and ascorbic acid under a comparable two-spray, full-RDN schedule in cv. Azad T-6, although absolute values here were lower, likely reflecting cultivar, ripening environment and soil-fertility differences. Helal *et al.* (2023) [10], working with controlled-release nano-urea, similarly reported that fruit-quality responses to nano-nitrogen sources are not always significant and can even show a trade-off, indicating that the response of tomato fruit quality to nano-urea is cultivar- and environment-dependent rather than uniformly positive.

Table 3. Effect of foliar application of nano-urea on fruit characters and yield of tomato

Treatment	Fruits plant ⁻¹	Days to 1st picking	Equatorial diameter (cm)	Polar diameter (cm)	Average weight of 10 fruits (g)	Yield plot ⁻¹ (kg)	Yield (q ha^{-1})
T_1	37.74	72.76	5.16	4.27	35.39	20.727	518.17
T_2	39.44	70.25	5.52	4.56	37.44	21.530	538.25
T_3	41.26	69.00	5.64	4.67	39.17	21.947	548.67
T_4	34.97	77.69	4.78	4.26	32.74	17.097	427.42
T_5	36.24	74.07	5.41	4.31	34.36	19.387	484.67
T_6	36.30	75.80	5.14	4.45	35.15	20.270	506.75
T_7	32.58	77.73	4.83	4.15	32.22	15.717	392.92
T_8	34.80	74.09	4.87	4.28	33.00	17.280	432.00
T_9	35.02	75.97	4.90	4.30	34.06	18.517	462.92
T_{10}	31.40	81.54	4.58	4.03	31.09	12.033	300.83
SEm±	0.36	1.99	0.20	0.05	0.70	0.944	23.596
CD (5%)	1.09	5.95	0.60	0.13	2.09	2.826	70.651
CV (%)	11.75	14.57	9.77	8.79	9.51	8.861	8.86

Cost of cultivation was lowest in T_{10} (Rs 1,71,910 ha^{-1} , no nitrogen applied) and highest in T_3 (Rs 1,86,653.55 ha^{-1}). T_3 recorded both the highest gross return (Rs 5,48,670 ha^{-1}) and net return (Rs 3,62,016.45 ha^{-1}), followed by T_2 and T_1 , while T_{10} gave the lowest returns, consistent with its lowest yield. The B:C ratio was highest in T_3 (2.94),

followed by T_2 (2.89) and T_1 (2.79) and lowest in T_{10} (1.75). These trends corroborate Mishra *et al.* (2020) [7] and Panda *et al.* (2020a) [8], who also recorded their highest B:C ratios under foliar nano-fertilizer sprays combined with an adequate basal fertilizer dose in tomato.

Table 4. Effect of foliar application of nano-urea on quality attributes of tomato fruit

Treatment	TSS ($^\circ\text{Brix}$)	Ascorbic acid ($\text{mg } 100 \text{ g}^{-1}$)	Titratable acidity (%)	Fruit firmness
T_1	3.33	17.32	0.26	0.53
T_2	3.50	17.66	0.28	0.57
T_3	3.47	17.68	0.29	0.59
T_4	3.27	16.75	0.27	0.52
T_5	3.30	16.43	0.24	0.53
T_6	3.40	16.31	0.26	0.53
T_7	3.43	16.02	0.28	0.51
T_8	3.30	16.46	0.27	0.52
T_9	3.47	16.49	0.25	0.52
T_{10}	3.27	16.29	0.25	0.50
SEm±	0.12	0.50	0.02	0.01
CD (5%)	NS	NS	NS	NS
CV (%)	5.89	5.41	5.43	4.48

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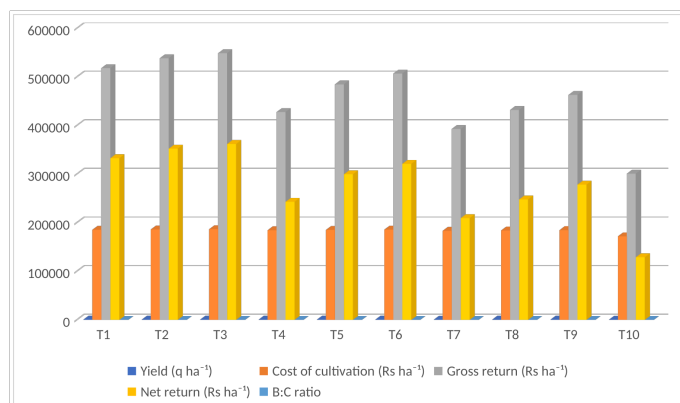


Table 5. Effect of RDN levels and foliar application of nano-urea on yield and economics of tomato cultivation

Treatment	Yield (q ha ⁻¹)	Cost of cultivation (Rs ha ⁻¹)	Gross return (Rs ha ⁻¹)	Net return (Rs ha ⁻¹)	B:C ratio
T ₁	518.17	185393.55	518170.00	332776.45	2.79
T ₂	538.25	186023.55	538250.00	352226.45	2.89
T ₃	548.67	186653.55	548670.00	362016.45	2.94
T ₄	427.42	184418.59	427420.00	243001.41	2.32
T ₅	484.67	185048.59	484670.00	299621.41	2.62
T ₆	506.75	185678.59	506750.00	321071.41	2.73
T ₇	392.92	183443.57	392920.00	209476.43	2.14
T ₈	432.00	184073.57	432000.00	247926.43	2.35
T ₉	462.92	184703.57	462920.00	278216.43	2.51
T ₁₀	300.83	171910.00	300830.00	128920.00	1.75

Conclusion

Foliar application of nano-urea, when used alongside an adequate basal dose of nitrogen, improved the growth, yield and profitability of tomato cv. Kashi Aman without significantly altering fruit biochemical quality. Application of 100 % RDN supplemented with two foliar sprays of nano-urea at 4 mL L⁻¹ (30 and 50 DAT) consistently emerged as the best-performing treatment, producing taller plants, earlier and more abundant flowering and fruit set, larger and heavier fruits, the highest yield (548.67 q ha⁻¹) and the best economic returns (net return Rs 3,62,016.45 ha⁻¹; B:C ratio 2.94) among all treatments evaluated. Since the trial was conducted for a single season at one location on a single cultivar, multi-location, multi-season and multi-cultivar trials are recommended before these findings are generalized for wider recommendation.

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