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Impact of nano urea on growth, yield attributes, yield, quality and economics of *Bt. cotton* (*Gossypium hirsutum* L.) under irrigated condition

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ABSTRACT

A two-year field experiment was conducted during *kharif* 2023–24 and 2024–25 at the Cotton Research Station, Junagadh Agricultural University, Junagadh, to evaluate the effect of foliar-applied nano urea with different levels of the recommended dose of nitrogen (RDN) on the growth, yield and economics of irrigated *Bt. cotton* hybrid G. Cot. Hy. 24 BG II. The experiment was laid out in a Randomized Block Design with 14 treatments and three replications. Treatments included different combinations of 100, 75 and 50% RDN with foliar sprays of urea (1 or 2%) or nano urea (2 or 4 ml/lit) applied at 40, 70 and 90 DAS. Pooled analysis revealed non-significant year and year $\times$ treatment interaction effects for most parameters. Application of 100% RDN + nano urea 4 ml/lit (T_{10}) produced significantly higher plant growth, dry matter, SPAD value, sympodial branches, bolls per plant, seed cotton yield (2433 kg/ha), lint yield (861 kg/ha) and stalk yield (5458 kg/ha) which is representing increases of 90.8% over the absolute control. Treatments T_9 (100 % RDN with foliar spray of nano urea 2 ml/ lit water at 40, 70 and 90 DAS), T_4 (100 % RDN + foliar spray of 2 % urea at 40, 70 and 90 DAS), T_3 (100 % RDN + foliar spray of 1 % urea at 40, 70 and 90 DAS), T_{12} (75 % RDN with foliar spray of nano urea 4 ml/ lit water at 40, 70 and 90 DAS) and T_{11} (75 % RDN with foliar spray of nano urea 2 ml/ lit water at 40, 70 and 90 DAS) were statistically at par with T_{10} . Treatment T_{11} (75% RDN + nano urea 2 ml/lit) achieved comparable yield and benefit ratio of 1.80 despite 25% lower soil nitrogen. Fibre quality and oil content remained unaffected, indicating that nano urea can partially replace soil-applied nitrogen while sustaining productivity and improving profitability.

Keywords: *Bt. cotton*; nano urea; foliar application; seed cotton yield; economics

INTRODUCTION

India's position in global cotton production is a study in disparities. India, the United States, and Brazil combined contribute 64% of the world's cotton area and 71% of the world's production. India has the biggest area under cotton of any nation, but this only translates to around 21% of world production because its average productivity of 448 kg/ha is far below that of top growers like Australia, China, Turkey, Brazil, Mexico, and the United States. Biotic and abiotic stresses together with growing competition from other crops have reshaped the sector considerably in recent years. According to the Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, India produced 299.26 lakh bales (170 kg each) of cotton in 2024-25 from 113.6 lakh hectares at a productivity of 448 kg lint/ha, with the area under cotton down 10.46 per cent and

output down 7.98 per cent on the previous year. Maharashtra, Gujarat, Karnataka, Madhya Pradesh, Punjab, Rajasthan, Haryana, Tamil Nadu, and Uttar Pradesh are the country's principal cotton-growing states, with Gujarat leading national output followed by Punjab and Maharashtra. Gujarat alone supplies close to 30 per cent of India's cotton; the Committee on Cotton Production and Consumption (COCPC) put the state's 2024-25 output at 84.01 lakh bales from 23.92 lakh hectares, an average yield of 597 kg/ha (PIB, 2024). Saurashtra, Kutch, and parts of North Gujarat form the state's main rainfed growing tracts; the area under *Bt* cotton continues to expand each year; and Surendranagar district records the highest output among Gujarat's districts (CICR, 2024-25). The yield potential of any crop is the outcome of a complex interplay of internal and external factors, and sound nutrient management plays a decisive role in realizing this potential across diverse agro-

climatic situations. Among agronomic interventions, nitrogen management assumes particular significance in cotton (*Gossypium hirsutum* L.) a long-duration, nutrient-exhaustive crop grown widely under irrigated conditions in India. Among plant nutrients, nitrogen (N) occupies a particularly central role in cotton. It sustains photosynthesis in the leaves, forms an integral part of protein synthesis and through its contribution to chlorophyll formation, the plant converts light into carbohydrates. Urea supplies more than 82% of the nitrogenous fertilizer used on Indian crops, with national consumption running to about 33 million tonnes a year. Too little nitrogen causes nutrient deficiency, which slows both vegetative and reproductive growth, leads to early aging of the plant and reduces yield. On the other hand, too much nitrogen promotes excessive vegetative growth, delays maturity and can also reduce crop productivity.

Conventional fertilizers such as urea, although used extensively, suffer from poor nutrient-use efficiency owing to losses through leaching, volatilization and fixation, which not only raise the cost of cultivation but also aggravate environmental problems such as eutrophication and greenhouse gas emissions. Nano-scale nitrogen fertilizers, such as nano urea, address these constraints by exploiting the principles of nanotechnology. Owing to their small particle size (<100 nm), large surface area and high reactivity, nano urea particles are absorbed more readily through the stomata and epidermal layers when sprayed on foliage, and release nutrients in a controlled, targeted manner that synchronizes nutrient supply with crop demand at critical growth stages while curtailing losses. Compared with conventional chemical fertilizers, nano fertilizers are preferred mainly for their efficiency and environmental compatibility. Conventional urea delivers nitrogen to the plant with only 30-50 per cent efficiency whereas nano urea exceeds 80 per cent. Since urea already accounts for 82 per cent of India's nitrogenous fertilizer consumption, some 33.6 million tonnes in 2019-20, nano urea and similar nano-nitrogen fertilizers hold real potential to improve nutrient-use efficiency and reduce input costs for farmers, particularly given how heavily today's agricultural productivity depends on fertilizer use (Pratima *et al.*, 2021). Incorporating foliar nano urea into the nutrient management schedule of *Bt.* cotton, in combination with reduced levels of soil-applied nitrogen, therefore offers a promising means of raising yield and improving the economics and sustainability of cotton production. Since information dealing directly with the response of *Bt.* cotton to nano urea remains limited, the present investigation was undertaken with the specific objective of evaluating the effect of foliar nano urea, applied together with varying levels of the recommended dose of nitrogen, on the growth, yield attributes, yield, quality and economics of *Bt.* cotton under irrigated conditions of the South Saurashtra Agro-climatic Zone of Gujarat.

MATERIALS AND METHODS

A field experiment entitled "Effect of nano urea on *Bt.* cotton under irrigated condition" was conducted during *kharif* 2023-24 and 2024-25 at the B-3 plot of the Cotton Research Station, Junagadh Agricultural University, Junagadh (21°30' N, 70°18' E) which falls under the South Saurashtra Agro-climatic Zone of Gujarat and experiences a semi-arid climate with hot, dry summers, moderate monsoon rainfall and cool, dry winters. The first shower of monsoon was received during third week of June in 2023 and fourth week of June in 2024. The crop growth periods of 2023-2024 and 2024-2025 saw total rainfall of 1700.7 and 2296.3 mm, respectively. The experimental soil was clayey in texture, slightly alkaline in reaction (pH 7.74-7.78), medium in available nitrogen (245-268 kg/ha) and phosphorus (23-27 kg/ha), and high in organic carbon and available potassium (386-401 kg/ha).

The *Bt.* cotton hybrid G. Cot. Hy. 24 BG II (SorathSwet Kanak), released by the Cotton Research Station, JAU, Junagadh in 2020 was used as the test crop. The experiment was laid out in a Randomized Block Design (RBD) with fourteen treatments replicated three times (42 plots), each gross plot measuring 6.30 m x 6.00 m with a net plot of 5.40 m x 2.40 m, at a spacing of 120 cm x 45 cm. The recommended dose of fertilizer (RDF) was 240-50-150 kg N-P₂O₅-K₂O/ha, with N applied in five splits (20% basal and 20% each at 30, 60, 90 and 120 DAS) and P₂O₅ and K₂O applied basally with a split top-dressing of K₂O at 30 DAS.

The fourteen treatments comprised: T₁: absolute control; T₂: 100% RDN + water spray at 30, 60 and 90 DAS; T₃ and T₄: 100% RDN + foliar urea at 1% and 2%, respectively; T₅ and T₆: 75% RDN + foliar urea at 1% and 2%; T₇ and T₈: 50% RDN + foliar urea at 1% and 2%; T₉ and T₁₀: 100% RDN + foliar nano urea at 2 and 4 ml/lit; T₁₁ and T₁₂: 75% RDN + foliar nano urea at 2 and 4 ml/lit; and T₁₃ and T₁₄: 50% RDN + foliar nano urea at 2 and 4 ml/lit, all foliar sprays being applied at 40, 70 and 90 DAS.

Observations were recorded on plant population, plant height (75, 125 DAS and harvest), dry matter accumulation (45, 75, 100 DAS), number of monopodial and sympodial branches, SPAD (chlorophyll) value (75 and 125 DAS), average boll weight, number of bolls per plant, ginning percentage, seed cotton yield, stalk yield, lint yield, and quality parameters (fibre length, fibre strength, micronaire value, oil content). Fibre quality parameters measured by digital Stapler at the cotton quality evaluation laboratory, cotton research station, J.A.U., Junagadh and oil content by nuclear magnetic resonance (NMR) spectroscopy method. Economics of each treatment was worked out in terms of cost of cultivation, gross realization, net realization and benefit:cost ratio, based on prevailing market prices (seed cotton Rs. 75/kg; cotton stalk Rs. 1/kg). Data were

statistically analyzed with RBD design by the procedure of Panse and Sukhatme (1985) and pooled analysis of variance was carried out over the two years of experimentation.

RESULTS

Growth parameters

Initial plant population and plant population at harvest were not significantly influenced by any treatment. Plant height, dry matter accumulation, number of sympodial branches and SPAD value were significantly influenced by the treatments. Treatment T₁₀ (100% RDN + nano urea 4 ml/lit) consistently recorded the significantly higher plant height at 75 DAS, 125 DAS and at harvest (130.50 cm pooled), remaining statistically at par with T₉ (100 % RDN with foliar spray of nano urea 2 ml/ lit water at 40, 70 and 90 DAS), T₄ (100 % RDN + foliar spray of 2 % urea at 40, 70 and 90 DAS), T₃ (100 % RDN + foliar spray of 1 % urea at 40, 70 and 90 DAS), T₁₂ (75 % RDN with foliar spray of nano urea 4 ml/ lit water at 40, 70 and 90 DAS) and T₁₁ (75 % RDN with foliar spray of nano urea 2 ml/ lit water at 40, 70 and 90 DAS), while the absolute control (T₁) recorded the significantly lowest height (75.83 cm) throughout. Dry matter accumulation at 45 DAS did not differ significantly among treatments, but at 75 and 100 DAS, T₁₀ recorded the significantly higher accumulation (1662 and 1988 kg/ha respectively) on par with T₉, T₄, T₃, T₁₂ and T₁₁. The number of monopodial branches remained statistically unaffected (2.00-2.33), whereas sympodial branches were significantly higher under T₁₀ (14.67), on par with the same group of treatments. SPAD value was significantly higher at both 75 DAS (70.67) and 125 DAS (64.83) under T₁₀, which was at par with treatment T₃, T₄, T₉, T₁₁ and T₁₂ (Table 1 & 2). Average boll weight and ginning percentage remained statistically unaffected by the treatments (pooled range 3.76-4.10 g and 32.16-35.31%, respectively). The number of bolls per plant was significantly higher under T₁₀ (33.22), on par with T₃, T₄, T₉, T₁₁ and T₁₂, against the lowest number (18.67) under T₁. The consistent superiority of treatment T₁₀ (100% RDN + foliar nano urea 4 ml/lit) across growth, yield and yield-attributing characters may be attributed to the nano-scale particle size and higher surface area of nano urea, which permits ready penetration through stomata and efficient translocation through plasmodesmata, thereby making nitrogen instantaneously available to actively growing meristematic tissues. Nitrogen being an essential constituent of protoplasm, protein and chlorophyll, its enhanced and timely availability through nano urea sprays likely favoured greater cell division and elongation, higher chlorophyll formation (reflected in higher SPAD values) and consequently better vegetative growth, more sympodial branches, greater boll retention and higher dry matter accumulation, ultimately translating into higher seed

cotton, lint and stalk yields. These findings are in close agreement with those reported by Hayyawati *et al.* (2018), Alzreejawi and Al-Juthery (2020), Reddy *et al.* (2022), Gousia *et al.* (2023), Sajjan *et al.* (2025) and Bhimashankar *et al.* (2024).

Seed cotton yield the principal economic parameter was significantly influenced by the treatments. The significantly higher seed cotton yield (2433 kg/ha), lint yield (861 kg/ha) and stalk yield (5458 kg/ha) were recorded under T₁₀ which was statistically at par with treatment T₃, T₄, T₉, T₁₁ and T₁₂, representing increases of 90.8% over the absolute control and 22.3% over 100% RDN with plain water spray (T₂). Among the 75% RDN treatments, foliar nano urea (T₁₁, T₁₂) produced seed cotton yield comparable to 100% RDN with conventional urea (T₃, T₄) indicating that a quarter of the soil-applied nitrogen could be substituted through foliar nano urea without yield penalty (Figure 1). Its markedly higher nutrient-use efficiency (>80%) relative to conventional urea (30-50%), its smaller particle size (20-50 nm) and its slow, targeted release pattern matching the critical nitrogen demand of squaring, flowering and boll-development stages can substitute a meaningful share of soil-applied nitrogen without penalising yield. This finding is corroborated by Modhvadiya *et al.* (2012), Basavanneppa *et al.* (2015), Malik *et al.* (2021) and Manibharathi *et al.* (2025) who similarly reported that a part of the recommended nitrogen dose could be compensated through foliar nutrition in *Bt. cotton*.

Quality parameters

Fibre length (27.10-28.47 mm), fibre strength (30.99-32.62 g/tex), micronaire value (4.49-4.99 µg/inch) and seed oil content (17.77-18.32%) were not significantly influenced by any treatment, indicating that the yield improvement obtained through nano urea and urea foliar sprays was achieved without deterioration of fibre or seed quality. The non-significant response of fibre quality traits and seed oil content confirms that these characters are predominantly governed by the genetic constitution of the hybrid rather than by the level or form of nitrogen nutrition, once the basic nutrient requirement of the crop is met, consistent with the reports of Singh *et al.* (2015), Zakzok *et al.* (2018), Kanjana (2020) and Omar *et al.* (2022).

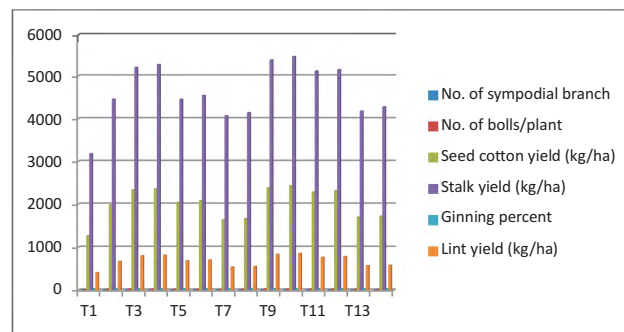


Fig 1: Graphical presentation on effect of nano urea on growth and yield parameters of *Bt. cotton* (Pooled results)

Table 1. Effect of nano urea on selected growth parameters of *Bt.* cotton (pooled mean of two years)

Treat. No.	Detail	Plant height (cm)			Dry matter accumulation (kg/ha)			SPAD value	
		At 75 DAS	125 DAS	At harvest	At 45 DAS	At 75 DAS	At 100 DAS	At 75 DAS	At 125 DAS
T ₁	Absolute control	63.61	73.50	75.83	442	1113	1441	38.50	35.67
T ₂	100 % RDN + water spray at 30, 60 and 90 DAS	82.83	97.67	101.50	475	1374	1702	59.17	51.83
T ₃	100 % RDN + foliar spray of 1 % urea	97.67	114.00	119.83	522	1569	1896	67.83	61.83
T ₄	100 % RDN + foliar spray of 2 % urea	100.83	117.50	124.50	525	1607	1936	69.83	63.33
T ₅	75 % RDN + foliar spray of 1 % urea	82.56	96.67	102.83	489	1403	1748	63.67	57.50
T ₆	75 % RDN + foliar spray of 2 % urea	85.89	99.33	104.67	496	1413	1741	64.17	58.50
T ₇	50 % RDN + foliar spray of 1 % urea	78.50	92.67	94.83	451	1265	1593	53.00	48.00
T ₈	50 % RDN + foliar spray of 2 % urea	79.95	96.33	96.17	458	1308	1636	54.50	49.00
T ₉	100 % RDN + foliar spray of nano urea 2 ml/ lit water	102.78	119.33	126.83	535	1631	1958	69.17	63.50
T ₁₀	100 % RDN + foliar spray of nano urea 4 ml/ lit water	108.50	123.83	130.50	543	1662	1988	70.67	64.83
T ₁₁	75 % RDN + foliar spray of nano urea 2 ml/ lit water	97.06	112.33	117.17	511	1528	1856	65.33	59.33
T ₁₂	75 % RDN + foliar spray of nano urea 4 ml/ lit water	99.22	114.83	119.33	514	1547	1875	66.17	61.00
T ₁₃	50 % RDN + foliar spray of nano urea 2 ml/ lit water	80.67	95.33	97.50	462	1334	1662	55.33	50.50
T ₁₄	50 % RDN + foliar spray of nano urea 4 ml/ lit water	82.06	96.33	100.83	466	1363	1691	56.83	51.17
S.E.m.±		4.52	4.27	4.03	25.22	50.89	66.10	2.48	2.65
C.D. at 5 %		12.82	12.13	11.44	NS	144	188	7.04	7.51
C.V. %		12.48	10.11	11.15	12.55	8.67	9.17	9.95	11.69
Y									
S.E.m.±		1.71		1.62	1.95	9.53	19.23	24.98	0.94
C.D. at 5 %		NS		NS	NS	NS	NS	NS	NS
Y x T									
S.E.m.±		5.81		6.05	7.29	35.66	71.96	93.48	3.51
C.D. at 5 %		NS		NS	NS	NS	NS	NS	NS

Table 2 : Effect of nano urea on selected growth and yield parameters of Bt. cotton (pooled mean of two years)

Treat. No.	No. of monopodial branch	No. of sympodial branch	No. of bolls/plant	Seed cotton yield (kg/ha)	Stalk yield (kg/ha)	Ginning percent	Lint yield (kg/ha)	Av. boll wt. (g)
T ₁	2.17	6.78	18.67	1275	3183	32.16	411	3.757
T ₂	2.00	11.00	27.05	1990	4460	33.84	674	4.002
T ₃	2.17	13.39	31.06	2337	5202	34.56	805	4.050
T ₄	2.33	14.00	31.78	2359	5273	34.77	821	4.074
T ₅	2.17	9.78	26.61	2046	4458	33.52	686	3.945
T ₆	2.17	10.78	27.06	2084	4548	33.93	707	3.982
T ₇	2.33	9.56	23.28	1650	4071	32.82	542	3.856
T ₈	2.00	9.84	24.17	1675	4147	33.17	556	3.881
T ₉	2.17	14.28	32.78	2387	5378	35.19	840	4.089
T ₁₀	2.00	14.67	33.22	2433	5458	35.31	861	4.104
T ₁₁	2.17	13.06	29.67	2285	5119	33.76	772	3.987
T ₁₂	2.33	13.22	30.61	2319	5152	34.05	788	4.022
T ₁₃	2.00	9.95	24.67	1712	4183	33.59	576	3.934
T ₁₄	2.17	10.22	25.45	1732	4280	33.69	585	3.953
S.Em.±	0.16	0.59	1.40	84	193	0.66	31.52	0.071
C.D. at 5 %	NS	1.68	3.97	239	548	NS	89	NS
C.V. %	18.68	12.65	12.43	10.22	10.21	4.80	11.23	4.37
Y								
S.Em.±	0.06	0.22	0.53	32	73	0.25	12	0.027
C.D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS
Y x T								
S.Em.±	0.23	0.84	1.979	119	273	0.94	44	0.100
C.D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS

Table 3. *Bt.* cotton quality parameters as influenced by nano urea (pooled mean of two years)

Treat. No.	Fibre length (mm)	Fibre strength (g/tex)	Micronaire value	Oil content (%)
T ₁	27.10	30.99	4.985	18.10
T ₂	28.36	31.90	4.717	18.42
T ₃	28.37	32.17	4.674	18.45
T ₄	28.33	32.33	4.567	18.48
T ₅	27.73	31.70	4.683	18.47
T ₆	27.77	31.79	4.745	18.64
T ₇	27.77	31.36	4.878	18.59
T ₈	27.93	31.15	4.875	18.60
T ₉	28.39	32.40	4.519	18.53
T ₁₀	28.47	32.61	4.492	18.59
T ₁₁	28.01	32.22	4.568	18.61
T ₁₂	28.12	31.73	4.631	18.53
T ₁₃	27.98	31.69	4.810	18.52
T ₁₄	28.00	31.89	4.755	18.45
S.Em.±	0.28	0.361	0.110	0.183
C.D. at 5 %	NS	NS	NS	NS
C.V. %	2.41	2.78	5.75	2.42
Y				
S.Em.±	0.104	0.137	0.042	0.069
C.D. at 5 %	NS	NS	NS	NS
Y x T				
S.Em.±	0.389	0.511	0.156	0.259
C.D. at 5 %	NS	NS	NS	NS

Economics

The data presented in Table 4 revealed that the cost of cultivation progressively increased with an increase in the level of RDN as well as with the use of nano urea over conventional urea, ranging from ₹76,098/ha under the absolute control (T₁) to ₹1,02,839/ha under treatment T₁₀, on account of the added cost of fertilizers and the nano urea or urea sprays. Notwithstanding the higher input cost, the highest gross return (₹1,02,839/ha) and the highest net return (₹85,094/ha) were recorded under treatment T₁₀, closely followed by T₉ (₹83,500/ha) (100 % RDN with foliar

spray of nano urea 2 ml/ lit water at 40, 70 and 90 DAS), T₄ (₹82,810/ha) (100 % RDN + foliar spray of 2 % urea at 40, 70 and 90 DAS), T₃ (100 % RDN + foliar spray of 1 % urea at 40, 70 and 90 DAS), T₃ (₹81,451/ha), T₁₂ (₹79,449/ha) T₁₂ (75 % RDN with foliar spray of nano urea 4 ml/ lit water at 40, 70 and 90 DAS) and T₁₁ (₹78,661/ha) (75 % RDN with foliar spray of nano urea 2 ml/ lit water at 40, 70 and 90 DAS), the same group of treatments that recorded the significantly higher seed cotton yield. The lowest net return (₹22,710/ha) was recorded under the absolute control (T₁) despite its lowest cost of cultivation, on account of its

markedly lower yield. With regard to benefit:cost ratio, the highest value (1.83) was recorded under treatment T₁₀ and T₄ followed closely by T₃ (1.82) and 1.80 (T₁₁ and T₁₂), all recording a benefit : cost ratio of 2.40, indicating that treatment T₁₁ (75% RDN + foliar spray of nano urea 2 ml/lit at 40, 70 and 90 DAS), despite receiving 25 per cent less soil-applied nitrogen than T₃, T₄, T₉ and T₁₀, produced an economic efficiency almost at par with the treatments

receiving the full recommended dose of nitrogen. From the economic standpoint, the superior benefit:cost ratio of T₁₁ despite 25% lower soil-applied nitrogen underlines the practical value of foliar nano urea as a partial substitute for conventional fertilizer, a conclusion consistent with the economic gains reported for nano urea in other crops by Kumar *et al.* (2021), Dodiya *et al.* (2024), Patel *et al.* (2024) and Zalavadiya *et al.* (2024).

Table 4. Economics of *Bt. cotton* cultivation as influenced by nano urea

Treat. No.	Gross return (Rs/ha)	Cost of cultivation (Rs/ha)	Net return (Rs/ha)	B:C ratio
T ₁	98808	76098	22710	1.30
T ₂	153710	94875	58835	1.62
T ₃	180477	99026	81451	1.82
T ₄	182123	99388	82810	1.83
T ₅	157908	93752	64156	1.68
T ₆	160848	94300	66548	1.71
T ₇	127821	87253	40568	1.46
T ₈	129772	87649	42123	1.48
T ₉	184403	100903	83500	1.83
T ₁₀	187933	102839	85094	1.83
T ₁₁	176494	97833	78661	1.80
T ₁₂	179077	99628	79449	1.80
T ₁₃	132583	89270	43313	1.49
T ₁₄	134180	90903	43277	1.48
Particulars	Market rate	Particulars	Market rate	
Seed cotton sale	Rs 75.00 /kg	MOP	Rs 37.00 /kg	
Cotton stalk sale	Rs 1.00 /kg	Nano urea	Rs 400 /lit.	
Urea	Rs 5.93 /kg	DAP	Rs 27.00 /kg	

CONCLUSION

From the two-year field investigation, it may be concluded that application of 75% of the recommended dose of nitrogen (RDN) together with three foliar sprays of nano urea at 2 ml/litre of water at 40, 70 and 90 DAS constitutes the most efficient nitrogen management practice for *Bt. cotton* under irrigated conditions, since it produced seed cotton yield, yield attributes and benefit:cost ratio statistically and economically comparable to the full recommended dose of nitrogen, while saving 25% of the

soil-applied nitrogen and reducing the associated fertilizer cost and chemical load on the soil. Where the highest absolute yield is the objective, 100% RDN combined with foliar nano urea at 4 ml/lit (T₁₀) remains the superior option. Overall, nano urea can effectively substitute a part of the soil-applied nitrogen in *Bt. cotton* without compromising growth, yield, fibre quality or profitability, supporting its adoption as a sustainable component of nitrogen management in irrigated cotton production systems of the South Saurashtra Agro-climatic Zone of Gujarat.

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