



RESEARCH ARTICLE

Foliar efficacy of urea formulations in *Bt* cotton for enhancing yield and nitrogen use efficiency under rainfed black calcareous soils

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Abstract

Inadvertent use of nitrogenous (N) fertilisers has resulted in low N use efficiency and cotton productivity in high yielding *Bt* cotton hybrids. Apparently, soil application of prilled urea is associated with substantial N losses posing serious threats to the ecosystem and environment. Consequently, foliar spray of N fertilisers is being practiced in rainfed cotton. However, literature on foliar efficacy of nano urea (12 %) in cotton remains limited. Therefore, a field experiment was conducted with 13 treatment combinations with urea and nano urea as foliar spray one-time at 35 days after sowing (DAS) and two-times at 35 and 55 DAS along with three recommended doses of nitrogen (100 %, 75 %, 50 % recommended dose of nitrogen (RDN)) and compared with foliar spray of urea once at 100 % RDN. The study results revealed few significant ($p < 0.05$) differences with foliar spray of urea formulations in growth and yield attributes over other treatments. Notably, nano urea two times spray + 100 % RDN significantly increased seed cotton (SC g plant⁻¹) and seed cotton yield (SCY kg ha⁻¹) by 9 % and 6 % respectively, compared to urea spray + 100 % RDN. Similarly, nano urea two times spray + 100 % RDN has significantly increased N concentration and uptake by 7 %, 12 % respectively compared to urea one time spray + 100 % RDN. In contrast, seed index and fiber quality were not significantly influenced by foliar spray of urea formulations. Economic calculations postulated that nano urea two times spray + 100 % RDN recorded the highest benefit to cost (BC), marginal cost benefit ratio (MCBR), with an additional net return of ₹4093 compared to other treatments. Overall, the study highlights the potential of urea formulations as foliar spray at 35 and 55 DAS with 100 % RDN in improving rainfed cotton production under black calcareous soil.

Keywords: *Bt*-hybrids; fiber quality; foliar nitrogen; nano urea; prilled urea; rainfed vertisol

Introduction

Nitrogen (N) management plays a pivotal role in sustaining cotton growth, metabolic processes and yield. Since the introduction of transgenic cotton in India (2002–2003), its large-scale adoption led to an increased demand for nitrogenous fertilisers such as urea, ammonium sulphate and ammonium nitrate, with application rates raising from 60–80 kg ha⁻¹ N to 100–120 kg ha⁻¹ in India for varieties and hybrids respectively, under rainfed and irrigated conditions. This increase was primarily due to the extended crop duration of *Bt* hybrids, which required an additional 25 % fertiliser dosage (1). Similarly, prilled urea consumption has increased nearly 30-fold over the past 5 decades from 0.6 MT in 1965 to 17.64 MT in 2015, although its use pattern remains abnormally skewed due to the urea subsidy scheme (USS) (2). A survey explained that farmers often believe higher urea application ensures greater seed cotton yield (SCY), while, excessive usage leads to several agronomic and environmental challenges (3).

The nitrogen use efficiency (NUE) of urea seldom exceeds 30–35 % due to substantial losses through fixation, leaching, denitrification and volatilisation, particularly in black calcareous soils (4). Excessive N fertilisation not only reduces efficiency but also induces toxicity, disrupting root development, delaying crop

maturity and increasing susceptibility of cotton to sap-sucking pests (5). Furthermore, the imbalanced application of urea has altered the nitrogen, phosphorous and potassium (NPK) ratio from 4:2:1 to 6.7:3.1:1 (6), exacerbating nutrient disparities in cotton growing areas. The stagnant NUE for phosphorus (P, 18–20 %) and potassium (K, 50–60 %) further compounds the inefficiencies of N (7). Despite these challenges, N remains indispensable for cotton growth and productivity. It is a fundamental constituent of chlorophyll, nucleic acids, hormones, proteins and plays a crucial role in *Bt* toxin (Cry2Ab) protein synthesis in transgenic cotton (8). Addressing the limitations of conventional fertilisers (CF) and the opportunities presented by nanotechnology, this study focuses on nano urea as a viable solution for sustainable N management in cotton production (6).

Nanofertilisers (NF) are nutrient carriers of nano dimensions (≈ 1–100 nm). Due to their unique properties including a high surface area to volume ratio, NF can enhance nutrient solubility, uptake and utilisation efficiency while minimising leaching and nitrification losses. Consequently, NF have the potential to mitigate eutrophication, greenhouse gas emissions, while improving nitrogen uptake and use efficiency (9). In addition, the subsidy burden on urea at ₹1958 bag⁻¹ from 2018 under USS, could be reduced effectively through NF (10). Although urea modified fertilisers enhance NUE, there is still a lack of comprehensive

evidence regarding their foliar effectiveness compared to traditional urea in cotton, especially under rainfed stress conditions. Additionally, the physiological and economic benefits of using nano urea at the recommended nitrogen levels in cotton are not yet clearly defined (11).

Recently Coromandel International Limited, Hyderabad, Telangana has developed nano urea (12 % N) as a complementary source to foliar spray of prilled urea (46 % N). Foliar spray of nano urea has been reported to significantly increase crop yields of rice and wheat sequence cropping by 4 % (12), wheat by 9 % (13), maize by 18 % (14), finger millet by 12 % (15) and rice by 4 % (16). Therefore, it was hypothesised that supplementary foliar spray of urea formulations may reduce the excessive use of prilled urea by improving NUE. Therefore, a field experiment was carried out with the following objectives. To study the response of urea formulations on growth, yield, fibre quality and economics of *Bt* cotton under rainfed black calcareous soil. To evaluate the multiple sprays of nano urea on cotton yield and fibre quality.

Materials and Methods

Experimental site

A field study was conducted during the kharif season of 2023 at ICAR-Central Institute for Cotton Research, Nagpur, Maharashtra, India (79° 03'0.41" E and 21° 01' 0.928" N, altitude 312 m above mean sea level). The soil at the experimental site belongs to the Panjari soil series. Surface soil (00–30 cm) samples were collected from 10 random locations of the experimental field. The soil samples were analysed for the physio-chemical properties following standard procedures. Initial soil results revealed that the experimental field belongs to a Vertisol, which is clay in texture with 90 % clay. The parent material was basaltic alluvium. The soil is neutral in pH (7.75) with normal EC (0.2 dS m⁻¹), medium in CaCO₃ content (20 %), low in organic carbon content (0.50 %), low in soil available N (142 kg ha⁻¹), P (7 kg ha⁻¹) and high in soil available K (830 kg ha⁻¹).

Weather conditions

The experimental field is situated in a tropical wet and dry climate of Maharashtra. The region experiences moderate to high rainfall from June to September followed by low rainfall in November and December, resulting in a total rainfall of 1244 mm. Mean monthly meteorological observations were recorded during the cotton season from June to December of 2023, which were recorded at meteorological observatory of ICAR-Central Institute for Cotton Research, Nagpur (Supplementary Fig. 1 and 2). Average monthly minimum and maximum temperatures are range between 14.5–

27.7 °C and 27.4–38.8 °C from June to December 2023. Similarly, average monthly minimum and maximum relative humidity are range between 40.8–46.7 % and 67.1–70.2 % respectively. However, the optimal climatic requirements for cotton are, an air temperature of 18–35 °C, relative humidity of 60–80 % and rainfall of about 700 mm.

Cotton management practices

A field experiment was carried out during the kharif season of 2023 to study the response of foliar spray of urea formulations on growth, yield, fiber quality, NUE and nutrient uptake of *Bt* cotton under rainfed black calcareous soil. The experimental design was a randomized block design (RBD) of 13 treatment combinations and 3 replications with a gross plot area of 47.52 m² and a net plot area of 29.00 m². The experimental plots received various N doses with 100 kg ha⁻¹ through urea and each of 50 kg ha⁻¹ as the recommended dose for P and K through single super phosphate (SSP), muriate of potash (MOP) (Table 1). Nitrogen at 100 % RDN received 100 kg of N through prilled urea in 3 split doses: one half at 18 DAS, the remaining halves at 40 and 70 DAS. Similarly, 75 % of RDN treatments received 75 kg of N ha⁻¹ in 2 split doses: one half at 18 DAS, the remaining half at 40 DAS. While 50 % RDN treatments received 50 kg of N ha⁻¹ at 18 DAS. Similarly, all the treatments received 50 kg each of P and K as basal at 18 DAS. Pendimethalin (38.7 % CS) at 700 mL acre⁻¹ as a pre-emergence herbicide was applied to control weeds before sowing of cotton. *Bt*-cotton hybrid Ajeet-155 BG-II was sown at row-to-row spacing of 90 cm and plant to plant spacing of 60 cm. The seeds were sown after the onset of the monsoon on 26 June 2023. Gap filling was done on 7 July 2023 i.e., 11 DAS. Nano urea (12 % N) provided by Coromandel International Limited, Hyderabad, Telangana, was applied at 3 mL L⁻¹ at 35 DAS for respective treatments, while for other treatment combinations, it was applied at 3 mL L⁻¹ at 35 DAS and 55 DAS respectively (Supplementary Table 1). Similarly, 5 mL L⁻¹ of prilled urea (46 % N) was sprayed at 35 and 55 DAS corresponding to the stages of square initiation and flowering respectively, when the plants have an increased need for nitrogen. A common control (water spray+ N₀P₀K₀) is practiced for understanding the foliar efficacy of urea formulations and NUE.

Plant morphological and yield observations

Five plants from each plot were tagged to determine the physiological (chlorophyll and SPAD values), growth (plant height, sympodia, monopodia, dry matter yield) and yield (bolls per plant, boll weight, seed cotton per plant, SCY) attributes. Average SPAD values of upper, middle and lower leaves of tagged plants from each treatment were recorded with a chlorophyll meter SPAD-502 Plus at 30 and 60 DAS. In addition, the fourth leaf from the top was collected

Table 1. Foliar spray details of the experiment (2023)

Short forms	Treatment combinations	N kg ha ⁻¹	P kg ha ⁻¹	K kg ha ⁻¹
T ₁	Nano urea-FS (one time) + 100 % RDN	100	50	50
T ₂	Urea FS (one time) + 100 % RDN			
T ₃	Nano urea -FS (two times) + 100 % RDN			
T ₄	Urea-FS (two times) + 100 % RDN			
T ₅	Nano urea -FS (one time) + 75 % RDN	75	50	50
T ₆	Urea-FS (one time) + 75 % RDN			
T ₇	Nano urea -FS (two times) + 75 % RDN			
T ₈	Urea-FS (two times) + 75 % RDN			
T ₉	Nano urea -FS (one time) + 50 % RDN	50	50	50
T ₁₀	Urea-FS (one time) + 50 % RDN			
T ₁₁	Nano urea -FS (two times) + 50 % RDN			
T ₁₂	Urea-FS (two times) + 50 % RDN			
T ₁₃	Control (water spray + N ₀ P ₀ K ₀)	0	0	0

FS- foliar spray; RDN- recommended dose of nitrogen.

from each treatment and macerated with 80 % acetone. The absorbance was measured at 645, 652 and 663 nm wavelength in a spectrophotometer to estimate the Chl-*a*, Chl-*b* and Chl-*T* (17). Similarly, ginning out turn, seed, lint and harvest index (HI) were calculated with Eqn. 1–4 by collecting 300 g of cotton from tagged plants. Further, fiber quality (staple length, bundle strength, uniformity index, micronaire and elongation index) was tested using a high volume instrument (HVI) at ICAR- Ginning Training Center (GTC), Nagpur. To determine the dry matter yield (kg ha⁻¹), tagged plants from each treatment were uprooted and air dried for 3 days, further dried in hot air oven at 65°C for 1 day. To monitor the sucking pest and boll worm incidence 25 sticky traps and 5 pheromone ha⁻¹ were installed at 50 and 60 DAS. Cotton picking was carried out 3 times at 120, 140 and 160 DAS.

$$\text{Ginning out turn (\%)} = \frac{\text{lint weight (g)}}{\text{seed cotton weight (g)}} \times 100 \quad (\text{Eqn. 1})$$

$$\text{Lint index} = \frac{\text{seed index} \times \text{Ginning out turn (\%)}}{100 - \text{Ginning out turn (\%)}} \quad (\text{Eqn. 2})$$

$$\text{Harvest index} = \frac{\text{lint weight (g)}}{\text{Total biomass (kg ha}^{-1}\text{)}} \times 100 \quad (\text{Eqn. 3})$$

$$\text{Seed index} = \text{weight of 100 seeds} \quad (\text{Eqn. 4})$$

Soil and plant analysis

Soil samples from the experimental field were collected at various depths (00–30 cm) prior to sowing and subsequent to harvest in order to understand the pre-harvest and post-harvest soil nutrient status. Cotton plant samples like, branch, leaf, bur, stalk and root were collected from dried plant samples to determine the plant nutrient status, nutrient uptake and NUE. Nutrient uptake and NUE were calculated by using Eqn. 5–8. NUE can be divided into 2 parts, nitrogen uptake efficiency (NUpE) and nitrogen utilisation efficiency (NUE) using Eqn. 6–8. NUpE represents the amount of nitrogen a plant can take up from external sources, while NUE describes the plant's ability to assimilate and remobilise nitrogen within its own tissues. The product of NUpE and NUE is the AUE (7). Agronomic use efficiency (AUE) is the increase in yield per unit of N fertiliser applied to the crop, measured as kg SCY kg⁻¹ N applied (Eqn. 9).

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)}}{100} \times \text{Cotton dry matter yield (kg ha}^{-1}\text{)} \quad (\text{Eqn. 5})$$

$$\text{N uptake efficiency (NUpE)} = \frac{\text{Nitrogen concentration in plant (\%)}}{\text{Nitrogen applied (kg ha}^{-1}\text{)}} \quad (\text{Eqn. 6})$$

$$\text{Nitrogen utilisation efficiency} = \frac{\text{Seed cotton yield (kg ha}^{-1}\text{)}}{\text{Nitrogen concentration in plant (\%)}} \quad (\text{Eqn. 7})$$

$$\text{Nitrogen use efficiency (NUE)} = \text{NUpE} \times \text{NUE} \quad (\text{Eqn. 8})$$

$$\text{AUE} = \frac{\text{Yield fertilised plot (kg ha}^{-1}\text{)} - \text{Yield control plot (kg ha}^{-1}\text{)}}{\text{Fertilizer applied (kg ha}^{-1}\text{)}} \quad (\text{Eqn. 9})$$

Economics

The SCY kilogram per hectare was multiplied with minimum support price (MSP) ₹7020 for 2023–2024 for medium staple cotton to calculate the gross monetary returns (18). The cost of cultivation for each plot was calculated by considering all the field activity charges and the cost of nano urea was taken as ₹500 L⁻¹ (maximum retail price (MRP) provided by Coromandel International Limited). Gross monetary returns, net monetary returns, benefit cost ratio and marginal cost benefit ratio was obtained by Eqn. 10–13 respectively.

$$\text{Gross monetary returns (₹ ha}^{-1}\text{)} = \text{minimum support price ₹quintal}^{-1} \times \text{Seed cotton yield (kg ha}^{-1}\text{)} \quad (\text{Eqn. 10})$$

$$\text{Net monetary returns (₹ ha}^{-1}\text{)} = \text{Gross monetary returns (₹ ha}^{-1}\text{)} - \text{Total cost of cultivation (₹ ha}^{-1}\text{)} \quad (\text{Eqn. 11})$$

$$\text{Benefit cost ratio} = \frac{\text{Net monetary returns (₹ ha}^{-1}\text{)}}{\text{cost of cultivation (₹ ha}^{-1}\text{)}} \quad (\text{Eqn. 12})$$

$$\text{Marginal cost benefit ratio} = \frac{\text{Increased benefit (₹ ha}^{-1}\text{)}}{\text{Increased cost (₹ ha}^{-1}\text{)}} \quad (\text{Eqn. 13})$$

Statistical analysis

Statistical analysis of data was carried out for all the growth, yield and nutrient concentration of cotton except economics, with analysis of variance (ANOVA) technique by using computer-based AGRES-AGDATA statistical software. Mean values were separated and ranking was completed by using Duncan's multiple range test (DMRT) at 5 % probability. To determine the differences among fertiliser treatments, contrast analysis was performed and 13 mutually orthogonal contrast pairs were compared to gain a better understanding of the treatment effects (19). Furthermore, Pearson correlation analysis was performed to understand the correlation between the growth and yield attributes of cotton.

Results

Chlorophyll and soil plant analysis development (SPAD) value

The foliar spray of urea formulations had no significant impact on chlorophyll and SPAD values of cotton (Table 2). However, T₃ had the highest chlorophyll *a* (1.74 ± 0.1 mg m⁻², 1.67 ± 0.1 mg m⁻²) and *b* (0.63 ± 0.1 mg m⁻², 0.84 ± 0.07 mg m⁻²) at 30 and 60 DAS respectively. This resulted in the highest chlorophyll *T* (1.00 ± 0.1 mg m⁻², 0.52 ± 0.04 mg m⁻²) at 30 and 60 DAS. Similarly, T₃ had the highest SPAD values (43 ± 2.9, 42 ± 0.5) at 30 and 60 DAS.

Growth attributes

The foliar spray of urea formulations significantly (*p* < 0.05) influenced the growth attributes of cotton except for monopodia. Cotton height, sympodial branches and dry matter yield results revealed a significant difference between the treatments. Two sprays of nano urea + 100 % RDN (T₃) recorded the highest plant height, sympodial branches and exhibited an increase of 8 %, 4 % respectively compared to urea spray + 100 % RDN (T₂) (Table 3). Besides, plant height of all the treatments was found to be

Table 2. Foliar efficacy of urea formulations on chlorophyll and SPAD values of Ajeet 155 under rainfed black calcareous soil (2023)

Units	30 DAS				60 DAS			
	Chlorophyll (mg m ⁻²)			SPAD	Chlorophyll (mg m ⁻²)			SPAD
	Chl- <i>a</i>	Chl- <i>b</i>	Chl- <i>T</i>		Chl- <i>a</i>	Chl- <i>b</i>	Chl- <i>T</i>	
100 % RDN								
T ₁	1.55 ± 0.4	0.66 ± 0.0	0.69 ± 0.1	41 ± 1.8	1.39 ± 0.4	0.61 ± 0.1	0.52 ± 0.3	40 ± 0.5
T ₂	1.41 ± 0.2	0.45 ± 0.2	0.67 ± 0.1	38 ± 2.4	1.48 ± 0.6	0.74 ± 0.1	0.51 ± 0.5	41 ± 0.7
T ₃	1.74 ± 0.1	0.63 ± 0.1	1.00 ± 0.1	43 ± 2.9	1.67 ± 0.1	0.84 ± 0.7	0.52 ± 0.4	42 ± 0.5
T ₄	1.35 ± 0.2	0.54 ± 0.2	0.73 ± 0.1	40 ± 2.1	1.41 ± 0.8	0.80 ± 0.3	0.44 ± 0.6	41 ± 0.1
75 % RDN								
T ₅	1.27 ± 0.1	0.56 ± 0.1	0.71 ± 0.0	41 ± 1.7	1.29 ± 0.5	0.64 ± 0.3	0.45 ± 0.7	41 ± 0.3
T ₆	1.20 ± 0.0	0.46 ± 0.1	0.79 ± 0.1	37 ± 0.7	1.25 ± 1.1	0.70 ± 0.1	0.48 ± 0.5	41 ± 0.6
T ₇	1.38 ± 0.4	0.49 ± 0.0	0.90 ± 0.1	36 ± 3.6	1.27 ± 0.5	0.44 ± 0.6	0.48 ± 0.5	42 ± 0.5
T ₈	1.39 ± 0.4	0.49 ± 0.0	0.96 ± 0.0	41 ± 3.8	1.19 ± 0.7	0.44 ± 0.4	0.49 ± 0.3	41 ± 0.7
50 % RDN								
T ₉	1.16 ± 0.0	0.42 ± 0.2	0.66 ± 0.3	39 ± 1.1	1.14 ± 0.8	0.52 ± 0.6	0.44 ± 0.1	40 ± 0.7
T ₁₀	1.20 ± 0.1	0.35 ± 0.1	0.53 ± 0.2	40 ± 1.3	1.15 ± 0.6	0.48 ± 0.3	0.50 ± 0.3	41 ± 0.1
T ₁₁	1.29 ± 0.2	0.62 ± 0.4	0.90 ± 0.4	39 ± 1.4	0.97 ± 0.6	0.40 ± 0.7	0.46 ± 0.7	40 ± 0.5
T ₁₂	1.19 ± 0.1	0.52 ± 0.1	0.68 ± 0.1	40 ± 1.1	0.80 ± 0.5	0.59 ± 0.1	0.48 ± 0.2	41 ± 0.4
Control								
T ₁₃	1.17 ± 0.0	0.36 ± 0.3	0.64 ± 0.1	35 ± 2.3	0.75 ± 0.2	0.35 ± 0.1	0.46 ± 0.7	40 ± 1.1
C.D(0.05)	NS	NS	NS	NS	NS	NS	NS	NS
SE(m)	0.13	0.10	0.10	1.32	0.24	0.13	0.04	1.10
SE(d)	0.19	0.15	0.14	1.87	0.34	0.19	0.06	1.56
C.V (%)	17.88	19.56	23.23	5.76	24.15	21.48	16.94	5.34

RDN-Recommended dose of nitrogen. ** Significant at 1 % probability level; * significant at 5 % probability level and NS – non-significant. Table values represent means of three replications and ± indicates the standard error between them. T₁: Nano urea-FS (one time) + 100 % RDN; T₂: Urea FS (one time) + 100 % RDN; T₃: Nano urea-FS (two times) + 100 % RDN; T₄: Urea-FS (two times) + 100 % RDN; T₅: Nano urea-FS (one time) + 75 % RDN; T₆: Urea-FS (one time) + 75 % RDN; T₇: Nano urea-FS (two times) + 75 % RDN; T₈: Urea-FS (two times) + 75 % RDN; T₉: Nano urea-FS (one time) + 50 % RDN; T₁₀: Urea-FS (one time) + 50 % RDN; T₁₁: Nano urea-FS (two times) + 50 % RDN; T₁₂: Urea-FS (two times) + 50 % RDN; T₁₃: Control (water spray + N₀P₀K₀).

Table 3. Foliar efficacy of urea formulations on growth attributes of Bt cotton hybrid Ajeet 155 under rainfed black calcareous soil (2023)

Treatment	Height	Monopodia	Sympodia	Dry matter yield
Units	(cm)	number	number	(kg ha ⁻¹)
100 % RDN				
T ₁	129 ± 5.6 ^a	2.23 ± 0.4	16.80 ± 1.4 ^a	4075 ± 426 ^{ab}
T ₂	126 ± 3.0 ^a	2.26 ± 0.5	16.60 ± 0.7 ^a	3855 ± 449 ^{abcd}
T ₃	136 ± 3.1 ^a	2.46 ± 0.4	17.26 ± 0.3 ^a	4316 ± 415 ^a
T ₄	124 ± 8.2 ^a	2.46 ± 0.3	17.26 ± 1.4 ^a	3924 ± 763 ^{abc}
75 % RDN				
T ₅	125 ± 5.0 ^a	2.20 ± 0.2	16.00 ± 1.5 ^{ab}	3815 ± 805 ^{abcd}
T ₆	127 ± 6.5 ^a	2.53 ± 0.3	15.73 ± 2.7 ^{ab}	3750 ± 603 ^{abcd}
T ₇	127 ± 3.5 ^a	2.33 ± 0.1	16.66 ± 1.2 ^a	3684 ± 721 ^{abcd}
T ₈	124 ± 3.0 ^a	2.40 ± 0.2	15.60 ± 3.1 ^{ab}	3609 ± 237 ^{abcd}
50 % RDN				
T ₉	126 ± 7.0 ^a	2.20 ± 0.2	13.73 ± 1.8 ^{bc}	3314 ± 241 ^{bcd}
T ₁₀	129 ± 5.3 ^a	2.46 ± 0.4	11.53 ± 1.7 ^c	2975 ± 214 ^{de}
T ₁₁	122 ± 3.6 ^a	2.60 ± 0.4	12.33 ± 0.7 ^c	3385 ± 521 ^{bcd}
T ₁₂	126 ± 7.7 ^a	2.40 ± 0.2	12.73 ± 0.3 ^c	3086 ± 647 ^{cde}
Control				
T ₁₃	109 ± 12.8 ^b	2.53 ± 0.4	11.46 ± 0.1 ^c	2573 ± 519 ^e
C.D (0.05)	10.03 [*]	NS	2.46 ^{**}	892.98 [*]
SE(m)	3.43	0.20	0.84	305.96
SE(d)	4.86	0.28	1.19	432.65
C.V (%)	4.76	14.52	9.80	14.96

RDN-Recommended dose of nitrogen. Table values represent means of 3 replications and ± indicates the standard error between them. Different letters indicate that they are significantly differ at ($p < 0.05$) using Duncan's multiple range test. ** Significant at 1 % probability level; *significant at 5 % probability level and NS – non-significant. T₁: Nano urea-FS (one time) + 100 % RDN; T₂: Urea FS (one time) + 100 % RDN; T₃: Nano urea-FS (two times) + 100 % RDN; T₄: Urea-FS (two times) + 100 % RDN; T₅: Nano urea-FS (one time) + 75 % RDN; T₆: Urea-FS (one time) + 75 % RDN; T₇: Nano urea-FS (two times) + 75 % RDN; T₈: Urea-FS (two times) + 75 % RDN; T₉: Nano urea-FS (one time) + 50 % RDN; T₁₀: Urea-FS (one time) + 50 % RDN; T₁₁: Nano urea-FS (two times) + 50 % RDN; T₁₂: Urea-FS (two times) + 50 % RDN; T₁₃: Control (water spray + N₀P₀K₀).

statistically on par with highest excluding control. Similarly, T₃ recorded a 12 % increase in dry matter yield compared to T₂. However, T₃ statistically did not differ from T₁, T₂, T₄, T₅, T₆, T₇ and T₈ respectively. A similar trend was observed with sympodial branches.

Yield attributes

Control had the lowest seed cotton (SC) and SCY and significantly ($p < 0.05$) differed with other treatments (Fig. 1). Among the foliar spray interventions, T₃ reported a 9 % and 6 % increase in SC and SCY respectively, compared to T₂. The highest boll weight recorded was 4.2 ± 0.1 g plant⁻¹ with T₃ (Table 4). This resulted in a significant ($p < 0.05$) seed cotton (181 ± 13 g plant⁻¹) and highly significant ($p < 0.01$) SCY (2640 ± 51 kg ha⁻¹) respectively. In contrast, the number of harvestable bolls plant⁻¹ and harvest index (HI) were not significantly influenced by foliar spray of urea formulations. However, T₃ had the highest number of harvestable bolls plant⁻¹ (31.3 ± 5.3) and HI (26.8 ± 1.3).

Seed index and fibre quality

The seed index and fibre quality were analysed and presented in (Table 5). No significant differences were observed with the foliar spray of urea formulations.

Cotton nutrient status

Plant N and P concentration were significantly influenced by the foliar spray of urea formulations. Among the foliar spray interventions, the highest N concentration (0.89 %) was recorded with T₃ and significantly increased by 7 % compared to T₂. However, T₂, T₄, T₁ and T₆ statistically did not differ with the highest. Similarly, T₃ and T₄ reported the highest P concentration and significantly increased by 4 % compared to T₂. However, T₁, T₄, T₅ and T₇ statistically did not differ with the highest. Furthermore, no significant difference in plant K concentration was observed with foliar spray of urea formulations. However, the highest K concentration was recorded with T₃ and increased by 6 % compared

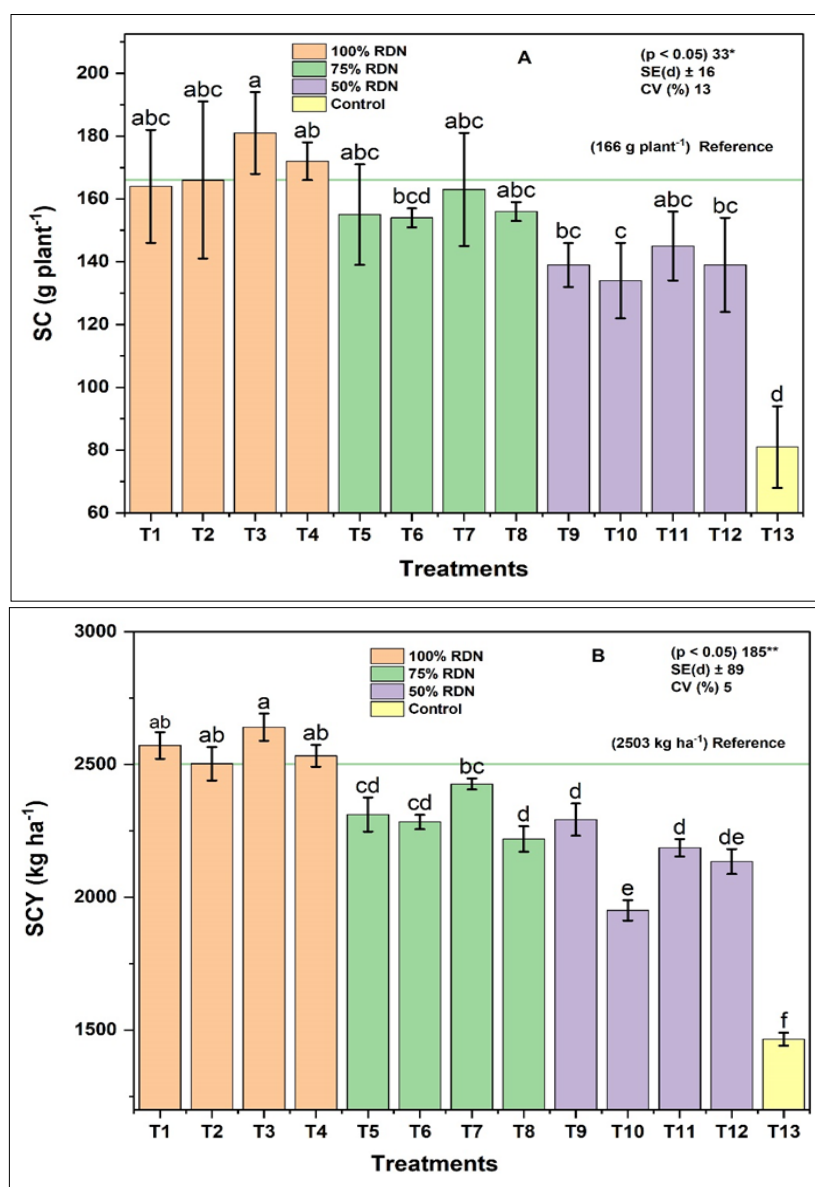


Fig. 1. Foliar efficacy of urea formulations on (A) seed cotton and (B) seed cotton yield of Ajeet 155 BG II under rainfed black calcareous soil (2023).

Error bars indicate mean ± SE, where SE= standard error. Bars with different letters differ significantly at ($p < 0.05$) and the means were compared by using DMRT. (The image was extracted by using Origin 2025b 10.25). T₁: Nano urea-FS (one time) + 100 % RDN; T₂: Urea FS (one time) + 100 % RDN; T₃: Nano urea-FS (two times) + 100 % RDN; T₄: Urea-FS (two times) + 100 % RDN; T₅: Nano urea-FS (one time) + 75 % RDN; T₆: Urea-FS (one time) + 75 % RDN; T₇: Nano urea-FS (two times) + 75 % RDN; T₈: Urea-FS (two times) + 75 % RDN; T₉: Nano urea-FS (one time) + 50 % RDN; T₁₀: Urea-FS (one time) + 50 % RDN; T₁₁: Nano urea-FS (two times) + 50 % RDN; T₁₂: Urea-FS (two times) + 50 % RDN; T₁₃: Control (water spray + N₀P₀K₀).

Table 4. Foliar efficacy of urea formulations on yield attributes of Ajeet 155 under rainfed black calcareous soil (2023)

Treatments	Boll plant ⁻¹	Boll weight	Harvest index	Nitrogen use efficiency	Agronomic use efficiency
Units	number	(g plant ⁻¹)		(%)	(kg ha ⁻¹)
100 % RDN					
T ₁	29.8 ± 1.9	3.8 ± 0.3 ^{abc}	24.8 ± 3.8	26 ± 0.49 ^d	10.9 ± 1.86 ^{bcd}
T ₂	26.7 ± 3.5	3.7 ± 0.0 ^{abc}	24.4 ± 4.1	25 ± 0.62 ^d	7.7 ± 1.33 ^d
T ₃	28.6 ± 5.7	4.2 ± 0.1 ^a	26.8 ± 1.3	26 ± 0.51 ^d	11.8 ± 1.89 ^{bcd}
T ₄	24.9 ± 3.9	4.1 ± 0.1 ^{ab}	22.4 ± 1.0	25 ± 0.40 ^d	10.7 ± 2.07 ^{bcd}
75 % RDN					
T ₅	28.8 ± 4.1	3.5 ± 0.1 ^c	26.0 ± 2.8	31 ± 0.85 ^c	11.3 ± 2.35 ^{bcd}
T ₆	26.5 ± 5.2	3.5 ± 0.6 ^{cd}	25.7 ± 4.6	30 ± 0.36 ^c	10.9 ± 2.83 ^{bcd}
T ₇	30.2 ± 4.2	3.7 ± 0.5 ^{abcd}	25.3 ± 1.5	32 ± 0.27 ^c	12.8 ± 3.00 ^{abc}
T ₈	31.3 ± 5.3	3.6 ± 0.1 ^{bcd}	26.7 ± 6.4	30 ± 0.64 ^c	10.1 ± 2.57 ^{cd}
50 % RDN					
T ₉	28.3 ± 2.1	3.6 ± 0.1 ^{bcd}	21.8 ± 3.4	46 ± 1.21 ^a	16.5 ± 4.28 ^a
T ₁₀	27.8 ± 1.2	3.7 ± 0.4 ^{bcd}	19.0 ± 2.4	39 ± 1.09 ^b	9.7 ± 4.43 ^{cd}
T ₁₁	23.0 ± 3.2	3.3 ± 0.18 ^{cd}	21.2 ± 2.9	44 ± 0.66 ^a	15.0 ± 4.63 ^{ab}
T ₁₂	27.9 ± 1.1	3.4 ± 0.2 ^{cd}	24.2 ± 3.4	43 ± 0.95 ^a	13.4 ± 4.18 ^{abc}
Control					
T ₁₃	22.2 ± 5.6	3.2 ± 0.2 ^d	28.6 ± 7.0	18 ± 1.66 ^e	-
C.D (0.05)	NS	0.53 [*]	NS	1.78 ^{**}	4.42 [*]
SE(m)	1.09	0.18	2.30	0.60	1.50
SE(d)	1.54	0.25	3.25	0.85	2.13
C.V (%)	13.84	8.58	16.32	3.29	22.26

RDN-Recommended dose of nitrogen. Table values represent means of three replications and ± indicates the standard error between them. Different letters indicates that mean values are differ significantly at ($p < 0.05$) using Duncan's multiple range test. ** Significant at 1 % probability level; * significant at 5 % probability level and NS – non-significant. T₁: Nano urea-FS (one time) + 100 % RDN; T₂: Urea FS (one time) + 100 % RDN; T₃: Nano urea-FS (two times) + 100 % RDN; T₄: Urea-FS (two times) + 100 % RDN; T₅: Nano urea-FS (one time) + 75 % RDN; T₆: Urea -FS (one time) + 75 % RDN; T₇: Nano urea-FS (two times) + 75 % RDN; T₈: Urea-FS (two times) + 75 % RDN; T₉: Nano urea-FS (one time) + 50 % RDN; T₁₀:Urea-FS (one time) + 50 % RDN; T₁₁: Nano urea-FS (two times) + 50 % RDN; T₁₂:Urea-FS (two times) + 50 % RDN; T₁₃: Control (water spray + N₀P₀K₀).

Table 5. Foliar efficacy of urea formulations on seed index and fibre quality of Ajeet 155 under rainfed black calcareous soil (2023)

Treatments	Ginning out turn	Seed index	Lint index	Staple length	Micronaire	Uniformity index	Bundle strength	Elongation index
Units	(%)	(g)	(g)	(mm)	(µg inch ⁻¹)	(%)	(g tex ⁻¹)	(%)
100 % RDN								
T ₁	36.90 ± 1.5	10.04 ± 0.4	5.84 ± 0.5	27.20 ± 0.7	4.0 ± 0.1	85.00 ± 0.8	26.76 ± 0.8	6.06 ± 0.1
T ₂	36.63 ± 1.3	10.04 ± 0.2	5.75 ± 0.4	26.70 ± 0.7	3.9 ± 0.3	84.66 ± 0.4	26.56 ± 1.1	5.86 ± 0.2
T ₃	37.59 ± 0.5	10.37 ± 0.4	6.16 ± 0.8	28.50 ± 0.7	4.0 ± 0.2	85.66 ± 0.4	26.66 ± 0.2	5.90 ± 0.1
T ₄	37.55 ± 2.6	10.14 ± 0.1	5.99 ± 0.3	27.20 ± 0.8	3.9 ± 0.3	85.33 ± 0.4	26.23 ± 0.4	5.93 ± 0.2
75 % RDN								
T ₅	37.15 ± 2.5	9.96 ± 0.2	5.79 ± 0.4	27.70 ± 0.3	3.8 ± 0.6	85.00 ± 0.0	26.93 ± 0.4	5.83 ± 0.1
T ₆	37.15 ± 1.3	9.94 ± 0.4	5.76 ± 0.7	27.60 ± 0.7	4.0 ± 0.5	85.33 ± 0.9	27.33 ± 1.0	5.73 ± 0.1
T ₇	37.44 ± 1.3	9.82 ± 0.5	5.88 ± 0.4	27.06 ± 0.5	3.9 ± 0.2	85.33 ± 0.4	28.13 ± 0.4	5.83 ± 0.1
T ₈	36.55 ± 1.0	9.93 ± 0.3	5.73 ± 0.4	27.20 ± 0.4	3.8 ± 0.3	85.00 ± 0.8	26.86 ± 0.6	5.73 ± 0.2
50 % RDN								
T ₉	37.66 ± 0.3	9.94 ± 0.2	6.01 ± 0.2	27.20 ± 0.2	3.8 ± 0.5	85.00 ± 0.8	26.03 ± 0.4	6.06 ± 0.4
T ₁₀	37.22 ± 1.9	9.70 ± 0.2	6.01 ± 0.4	27.23 ± 0.2	3.7 ± 0.1	84.66 ± 0.4	26.66 ± 0.6	6.03 ± 0.2
T ₁₁	37.59 ± 0.5	9.80 ± 0.1	5.90 ± 0.2	27.06 ± 1.0	3.8 ± 0.3	85.33 ± 0.4	26.33 ± 0.9	5.83 ± 0.4
T ₁₂	36.88 ± 1.3	9.63 ± 0.3	5.87 ± 0.4	27.26 ± 1.4	3.9 ± 0.1	85.00 ± 0.0	27.06 ± 0.7	5.86 ± 0.2
Control								
T ₁₃	36.33 ± 2.4	9.65 ± 0.1	5.56 ± 0.2	27.10 ± 0.5	3.6 ± 0.4	84.66 ± 0.4	26.40 ± 0.6	5.66 ± 0.2
C.D (0.05)	NS	NS	NS	NS	NS	NS	NS	NS
SE(m)	0.94	0.19	0.26	0.42	0.20	0.42	0.42	0.14
SE(d)	1.33	0.27	0.37	0.60	0.28	0.60	0.59	0.20
C.V (%)	4.39	3.40	7.85	2.71	9.07	0.87	2.74	4.34

RDN-Recommended dose of nitrogen. Table values represent means of 3 replications and ± indicates the standard error between them. ** Significant at 1 % probability level; * significant at 5 % probability level and NS – non-significant. T₁: Nano urea-FS (one time) + 100 % RDN; T₂: Urea FS (one time) + 100 % RDN; T₃: Nano urea-FS (two times) + 100 % RDN; T₄: Urea-FS (two times) + 100 % RDN; T₅: Nano urea-FS (one time) + 75 % RDN; T₆: Urea-FS (one time) + 75 % RDN; T₇: Nano urea-FS (two times) + 75 % RDN; T₈: Urea-FS (two times) + 75 % RDN; T₉: Nano urea-FS (one time) + 50 % RDN; T₁₀:Urea-FS (one time) + 50 % RDN; T₁₁: Nano urea-FS (two times) + 50 % RDN; T₁₂:Urea-FS (two times) + 50 % RDN; T₁₃: Control (water spray + N₀P₀K₀).

to T₂ (Fig. 2).

Nutrient uptake

The foliar spray of urea formulations had a significant effect on the NPK uptake (kg ha⁻¹) of cotton (Fig. 2). The NPK uptake calculation revealed a clear significant difference between the treatments. T₃ recorded the highest NPK uptake and significantly increased by 16 %, 23 %, 13 % compared to T₂.

Nitrogen uptake and agronomic use efficiency

The NUE and AUE decrease with an increase in N application. The lowest NUE was recorded with the control (water spray + N₀P₀K₀) and was statistically differ with other treatments (Table 4). A highly significant ($p < 0.01$) NUE (46 ± 1.21) was recorded with T₁₀ and statistically on par with T₁₁ and T₁₂ respectively. Similarly, the lowest AUE (7.7 ± 1.33) was recorded with T₂ (urea spray + 100 % RDN). The significantly highest AUE (16.5 ± 4.28) were recorded with T₉ (nano

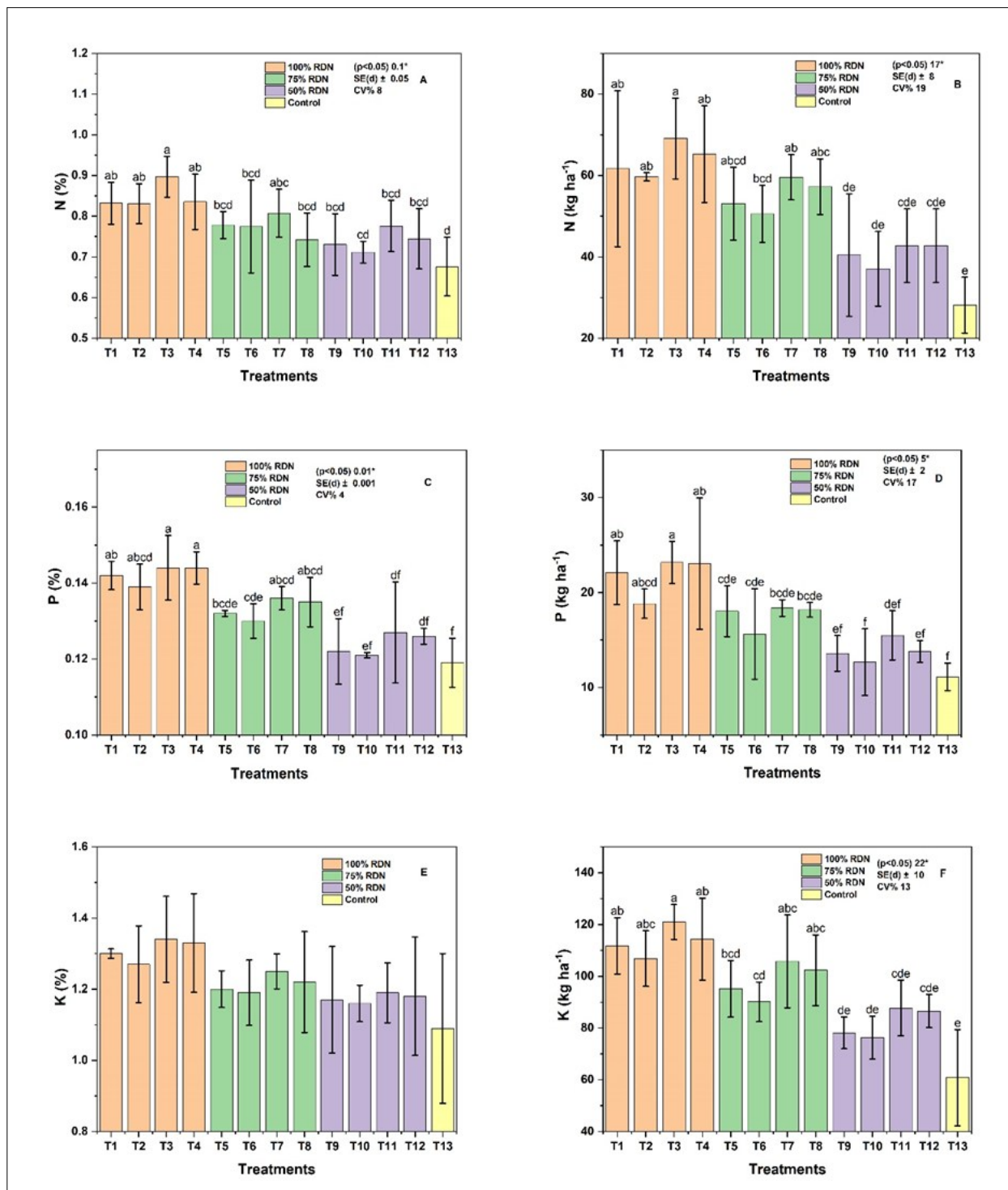


Fig. 2. Foliar efficacy of urea formulations on nutrient concentration and uptake (A, B) Nitrogen (C, D) phosphorous (E, F) potassium in Ajeet 155 BG II under rainfed black calcareous soil (2023).

Error bars indicate mean ± SE, where SE= standard error. Bars with different letters differ significantly at ($p < 0.05$) and the means were compared by using DMRT. (The image was extracted by using Origin 2025b 10.25). T₁: Nano urea-FS (one time) + 100 % RDN; T₂: Urea FS (one time) + 100 % RDN; T₃: Nano urea-FS (two times) + 100 % RDN; T₄: Urea-FS (two times) + 100 % RDN; T₅: Nano urea-FS (one time) + 75 % RDN; T₆: Urea-FS (one time) + 75 % RDN; T₇: Nano urea-FS (two times) + 75 % RDN; T₈: Urea-FS (two times) + 75 % RDN; T₉: Nano urea-FS (one time) + 50 % RDN; T₁₀: Urea-FS (one time) + 50 % RDN; T₁₁: Nano urea-FS (two times) + 50 % RDN; T₁₂: Urea-FS (two times) + 50 % RDN; T₁₃: Control (water spray + N₀P₀K₀).

urea spray + 50 % RDN). However, T₁₁ and T₁₂ (urea 2 times spray + 50 % RDN, nano urea 2 times spray + 50 % RDN) was found to be statistically on par with the highest.

Economics

Economic calculations of various treatments, indicate that the application of higher N doses resulted in increased cultivation costs (Table 6). The benefit cost ratio (1.27 B:C) was highest with T₃ followed by T₁ and T₂. Similarly, gross monetary returns (GMR) and net monetary returns (NMR) were highest with T₃. This treatment also recorded a 6.4 % marginal cost benefit ratio (MCBR) and an additional net benefit of ₹4093 respectively.

Correlation between growth and yield attributes

The correlation coefficients revealed a significant relationship between growth and yield attributes apart from monopodia. A highly positive correlation was observed between SCY and plant height (0.81**), sympodia (0.95**), DMY (0.99**), boll weight (0.95**). Furthermore, a positive correlation was also observed between the number of bolls (0.68*) and SCY (Fig. 3). However, all the attributes had a negative correlation with monopodial branches. Similarly, bolls per plant had a non-significant positive correlation apart from cotton height, which had a significant positive correlation. Similarly, HI and NUE also had a non-significant correlation with all the attributes. Moreover, variance inflation factor (VIF) analysis indicated significant multicollinearity among seed cotton, SCY, with VIF values exceeding 30. There was moderate multicollinearity between sympodia and dry matter yield, as shown by a VIF of approximately 9. In contrast, plant height and monopodia showed no signs of multicollinearity, with VIF values below 2 (Supplementary Table 2).

Discussion

Supplementary foliar application of N is key to improve cotton productivity in the calcareous soils of central India, where low N

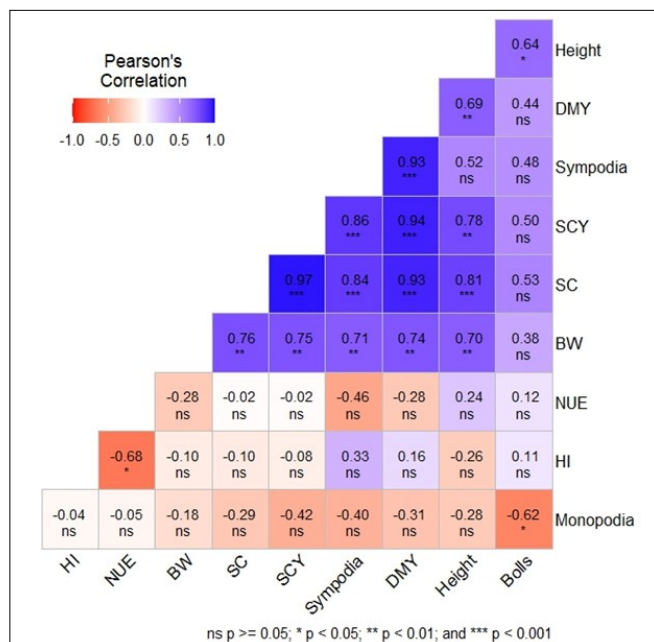


Fig. 3. Correlation matrix on foliar spray of urea formulations (2023).

DMY- Dry matter yield, Bolls - Number of bolls; BW- boll weight; HI- Harvest index; NUE- Nitrogen use efficiency; SC- Seed cotton; SCY- Seed cotton yield. (The image was extracted by using metan, ggcorrplot packages in RStudio (R Core Team, 2013)).

availability during the reproductive stage is a major limitation under rainfed conditions. To address these challenges, foliar spray of urea formulations was evaluated under rainfed black calcareous soils one time at 35 DAS. The results of our study revealed the significant impact of urea formulations on increasing cotton growth and yield. Foliar application of urea formulations resulted in increased plant height, sympodia, dry matter yield, higher seed cotton and SCY. This may be due to, when N is applied as foliar spray, its particle size (≤ 100 nm) might assist in penetrating the leaf surface through stomatal openings ($22\text{--}105\ \mu\text{m}^2$) (20) and in movement through

Table 6. Foliar efficacy of urea formulations on economics of Ajeet 155 under rainfed black calcareous soil (2023)

Treatments	Cost of cultivation	Gross returns	Net returns	B:C	Cost		Benefits		Net benefit	MCBR
					Increased cost	Decreased benefit	Decreased cost	Increased benefit		
Units	₹ha ⁻¹	₹ha ⁻¹	₹ha ⁻¹		₹ha ⁻¹	₹ha ⁻¹	₹ha ⁻¹	₹ha ⁻¹	₹ha ⁻¹	
100 % RDN										
T ₁	81000	180554.4	99554.4	1.23	0	0	0	0	0	0
T ₂	80304	175710.6	95406.6	1.19	0	696	4843.8	0	-4147.8	0
T ₃	81750	185398.2	103648.2	1.27	750	0	0	4843.8	4093.8	6.4
T ₄	80858	177816.6	96958.6	1.20	0	142	2737.8	0	-2595.8	0
75 % RDN										
T ₅	78500	162302.4	83802.4	1.07	0	2500	18252	0	-15752	0
T ₆	77250	160336.8	83086.8	1.08	0	3750	20217.6	0	-16467.6	0
T ₇	79200	170445.6	91245.6	1.15	0	1800	10108.8	0	-8308.8	0
T ₈	77804	155844.0	78040.0	1.00	0	3196	24710.4	0	-21514.4	0
50 % RDN										
T ₉	76000	160968.6	84968.6	1.12	0	5000	19585.8	0	-14585.8	0
T ₁₀	75304	136960.2	61656.2	0.82	0	5696	43594.2	0	-37898.2	0
T ₁₁	76696	153527.4	76831.4	1.00	0	4304	27027	0	-22723	0
T ₁₂	75858	149877.0	74019.0	1.00	0	5142	30677.4	0	-25535.4	0
T ₁₃										
Control	73250	125658.0	52408.0	0.72	0	7750	54896.4	0	-47146.4	0

RDN-Recommended dose of nitrogen. Data was not subjected to statistical analysis. T₁: Nano urea-FS (one time) + 100 % RDN; T₂: Urea FS (one time) + 100 % RDN; T₃: Nano urea-FS (two times) + 100 % RDN; T₄: Urea-FS (two times) + 100 % RDN; T₅: Nano urea-FS (one time) + 75 % RDN; T₆: Urea-FS (one time) + 75 % RDN; T₇: Nano urea-FS (two times) + 75 % RDN; T₈: Urea-FS (two times) + 75 % RDN; T₉: Nano urea-FS (one time) + 50 % RDN; T₁₀: Urea-FS (one time) + 50 % RDN; T₁₁: Nano urea-FS (two times) + 50 % RDN; T₁₂: Urea-FS (two times) + 50 % RDN; T₁₃: Control (water spray + N₀P₀K₀).

plasmodesmata. The tiny size and distinct characteristics of nano urea allow it to easily penetrate through cotton leaf. Due to its extremely small size, nano urea can efficiently enter leaves, ensuring N is released in a regulated way (13). This resulted in a prolonged supply of N throughout the cotton growth period. Furthermore, nano urea effectively meets the immediate crop N requirement which activates the enzymatic activities and protein assimilation pathways, thereby enhancing plant height, sympodial branches and dry matter yield (16). The combined application of nano urea and RDN has been shown to significantly improve the growth and yield of various crops (21, 22). The study demonstrated an increasing trend in growth and yield attributes of cotton with higher doses of RDN along with urea formulations (Fig. 1). Foliar spray of urea formulations had significantly improved chlorophyll and SPAD values of cotton, which in turn enhanced porphyrin synthesis, a key precursor of chlorophyll required for photosynthesis. This improvement promoted a higher number of sympodial branches, ultimately contributing to greater boll production, boll weight, seed cotton and SCY. Furthermore, nutrient uptake exhibits a strong positive correlation with SCY and cotton nutrient concentration. However, SC and SCY exhibited a higher multicollinearity, which may be to the absolute control (no fertiliser) treatment. In this study, significant differences in nutrient uptake values were observed, which were influenced by the variations in SCY across the treatments. The application of 100 % RDN along with foliar spray of urea formulations led to a significant increase in N uptake which was governed by higher N concentration in cotton. This increase can be result of enhanced soil fertility and prolonged N availability to cotton. As observed in our study, the increase in N concentration followed by foliar spray of urea formulations is likely due to the low particle size (≤ 100), which increases the total surface area to volume ratio aiding in the retention of N, avoiding nitrification, leaching and fixation losses. This mechanism results in a controlled release of nutrients, making N available to the plant over an extended period. The higher P uptake and concentration might be due to the positive relationship between N and P uptake, as N intake increases, P uptake rises correspondingly (23).

Nitrogen use efficiency usually decreases as fertiliser dose increases due to several losses such as fixation, leaching, denitrification and volatilisation losses. This decline is evident in the reduced use efficiency observed under higher N levels, likely because the increase in yield was less than the supply from both soil and fertiliser. Similar results were noticed where higher N application rates led to decreased agronomic use efficiency due to soil losses. Additionally, the combined application of prilled urea along with foliar spray of urea formulations might have helped to address low N availability during reproductive stages. Moreover, treatments with minimal or no fertiliser application reduced the cost of cultivation compared to those with higher fertiliser doses, primarily due to the increased cost of fertilisers and the expenses associated with their application at higher levels. In this study, the treatment T₃ (2 sprays of nano urea + 100 % RDN) recorded the highest cost of cultivation, which can be attributed to the higher cost of nano urea along with prilled urea. Despite these higher costs, this treatment also yielded the highest gross and net returns, driven by the increased SCY. Nevertheless, no significant differences were observed between T₁, T₂ and T₄ with respect to growth, yield attributes, nutrient concentration and uptake. This could be attributed to the relatively low N concentration in nano urea (12 %) compared to prilled urea

(46 %). In addition, prilled urea applied as foliar spray is also absorbed rapidly and assimilated by cotton leaves through the epidermis and stomata. Under rainfed conditions cotton N demand was effectively met by urea formulations during critical growth stages (squaring and flowering). Similar findings were reported in wheat (7). However, higher doses of prilled urea (>1 %) as foliar spray often cause leaf scorching and burning especially under high temperatures which adversely affects plant growth.

Conclusion

Foliar spray of nano urea 2 times + 100 % RDN (T₃) significantly enhanced cotton growth [(height 4 %) and (sympodia 8 %)], [(seed cotton 6 %) and (SCY 9 %)], [(plant nitrogen concentration 7 %) and (uptake 12 %)]. However, all these parameters were statistically did not differ with T₁, T₂ and T₄. Further, T₃ recorded an additional net benefit of ₹4093 compared to the other treatments. The findings indicate that nano urea is effective as a foliar supplement when applied twice during 35 and 55 DAS along with the full recommended N levels. However, its advantages decrease when N levels are reduced. Therefore, nano urea should be considered a synchronised N requirement during critical stages (squaring and flowering) and yield stabilising input rather than either a complete or partial replacement for soil applied N fertiliser levels for rainfed Bt cotton.

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Authors' contributions

AM conceptualised the study and drafted the manuscript. DB performed the statistical analysis and contributed to manuscript editing. TH conducted the experiments and prepared the figures. CRM performed soil and plant analysis. AST guided and supported the study. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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