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Effect of nano nitrogen on growth, yield and economics of *Bt* cotton

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Abstract
A field experiment was conducted at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Raichur to investigate the effect of nano nitrogen on growth, yield and economics of *Bt* cotton during the *kharif* season 2022. The experiment was laid out in split plot design with three main plots consists of different doses of nitrogen: M1 -100% N, 2022, M2 -75% N, and M3-50% N, 2022 and five subplots with different concentrations of nano nitrogen (S1: Spraying of 0.4% nano nitrogen at flowering & boll initiation stages; S2: Spraying of 0.4% nano nitrogen at flowering, boll initiation & boll development stages; S3: Spraying of 0.6% nano nitrogen at flowering & boll initiation stages; S4: Spraying of 0.6% nano nitrogen at flowering, boll initiation & boll development stages; S5: Control (without spraying) and replicated thrice. The results revealed that significantly higher plant height, sympodial branches, dry matter accumulation, seed cotton yield, gross returns, net returns was recorded by 100% N (176.9cm, 27.1, 430.31 g plant^{-1}, 3388 kg ha^{-1}, Rs. 271024 ha^{-1} and Rs. 188736 ha^{-1}respectively) followed by 75% RDN (168 cm, 26.7 and 426.91 g plant^{-1}, 3376 kg ha^{-1}, Rs. 270112 ha^{-1} and Rs. 188291 ha^{-1} respectively) which found *on par* with each other. However higher BC ratio of 3.30 was recorded by 75% RDN followed by 100% RDN (3.29) which found comparable with each other.
Among the sub plots, foliar application of nano urea @ 0.6 per cent each at 90, 100 and 135 DAS has recorded significantly higher plant height (180.8 cm), sympodial branches (28.5), dry matter accumulation (429.42 g plant^{-1}), gross returns (Rs. 278784 ha^{-1}) net returns (Rs. 195414 ha^{-1}) followed by foliar application of nano urea @ 0.4 per cent each at 90, 100 and 135 DAS (173.3 cm, 28 and 428.52 g plant^{-1}, 3465 kg ha^{-1}, Rs. 277238 ha^{-1} and Rs. 194768 ha^{-1}respectively) which found comparable to each other. However higher BC ratio of 3.36 was recorded by foliar application of nano urea @ 0.4 per cent each at 90, 100 and 135 DAS followed by foliar application of nano urea @ 0.6 per cent each at 90, 100 and 135 DAS (3.34).

Keywords: Plant height, sympodial branches and drymatter production

1. Introduction
"Cotton (*Gossypium hirsutum* L.), popularly known as the "king of fibres", is the most important fibre crop worldwide and plays a key role in the Indian economy by supplying raw material to the textile industry and contributing to yarn and fabric trade. At present, a major share of the global cotton area is under Bt cotton cultivation. The Indian textile sector contributes about 5 per cent to the gross domestic product (GDP), 14 per cent to industrial output, and 11 per cent to total export earnings (Anon, 2021) [2]. Globally, India occupies nearly 40 per cent of the cotton-growing area, but contributes only 21 per cent of total cotton production. Although India has the largest area under cotton, its productivity (439 kg ha^{-1}) is much lower than that of major cotton-producing countries such as Australia (2002 kg ha^{-1}), China (1971 kg ha^{-1}), Turkey (1828 kg ha^{-1}), Brazil (1771 kg ha^{-1}), Mexico (1599 kg ha^{-1}) and the USA (1061 kg ha^{-1}) (Anon, 2022) [1]. Efforts to enhance cotton productivity include genetic improvement, better crop management practices, optimized crop geometry, quality seed availability, input subsidies, public-private collaboration, effective extension programmes, and improved integrated nutrient and pest management. The low productivity of cotton in India is mainly due to the fact that more than 65 per cent of the cotton area is rainfed, along with low fertilizer application and poor fertilizer use efficiency.

Among the different production limitations, insufficient and imbalanced nutrient supply to the cotton crop is regarded as a major constraint. In Karnataka, cotton is cultivated over an area of 8.97 lakh hectares, producing 21.48 lakh bales with an average productivity of about 407 kg ha^{-1} (Anon, 2022) [1]. Nutrient management in cotton is inherently complex because vegetative and reproductive growth occur simultaneously during the peak growth period.

Nano-fertilizers improve crop growth, yield and quality by enhancing nutrient use efficiency and lowering input costs. They enable site- and stage-specific nutrient delivery, synchronized with crop growth, and possess a higher surface area that facilitates metabolic activities. This results in enhanced photosynthetic efficiency, thereby increasing dry matter accumulation and yield. In cotton, foliar application of liquid nano urea at flowering, boll initiation and boll development stages meets the nitrogen demand and leads to improved productivity and fibre quality. Sustainable enhancement of crop productivity can be achieved through the judicious integration of conventional fertilizers with nano-fertilizers. Foliar application of nano nitrogen allows a 25 per cent reduction in conventional nitrogen fertilizers. The combined use of soil-applied fertilizers and foliar nano nitrogen application results in higher seed cotton yield, increased net returns, and proves to be economically viable.

2. Materials and Methods

The present field study was conducted during kharif, 2022 to evaluate the effect of nano nitrogen on growth, yield and economics of Bt cotton. The experiment was executed at MARS, UAS, Raichur. The trial was arranged in a split plot design with three replications, involving 15 treatment combinations consisting of three nitrogen levels in the main plots and five concentrations of nano nitrogen in the subplots. The main plot treatments included M_1 - 100% N, M_2 - 75% N and M_3 - 50% N, while the subplot treatments comprised five nano nitrogen concentrations (S_1: foliar spray of 0.4% nano nitrogen at flowering and boll initiation stages; S_2: foliar spray of 0.4% nano nitrogen at flowering, boll initiation and boll development stages; S_3: foliar spray of 0.6% nano nitrogen at flowering and boll initiation stages; S_4: foliar spray of 0.6% nano nitrogen at flowering, boll initiation and boll development stages; S_5: control without spraying). The hybrid US-7067 was used for sowing, maintaining a spacing of 90 × 60 cm. Observations on plant height (cm), number of sympodial branches and total dry matter production (kg ha^{-1}) were recorded. At harvest, seed cotton yield, gross returns, net returns and benefit-cost ratio were computed. The experimental data recorded at various crop stages were statistically analyzed following the procedure outlined by Panse and Sukhatme (1978) [13]. The F-test was applied at P = 0.05, and critical difference (CD) values were worked out wherever the F-test was significant.

3. Results and Discussion

3.1 Growth parameters

Significantly higher taller plant height (176.9 cm), sympodial branches per plant (27.1), total dry matter accumulation (430.31 g plant^{-1}) was recorded with the 100 per cent recommended dose of nitrogen (M3), followed by 75 per cent of the recommended nitrogen dose (M2) (168 cm), sympodial branches (26.7), total dry matter accumulation (426.91 g plant^{-1}) which found *on par* with M3. While application of recommended nitrogen dose (M1- 50% N) resulted in significantly lower plant height of 162.5 cm, sympodial branches per plant (23.3), total dry matter accumulation (376.41 g plant^{-1}) (Table 1). Higher nutrient levels resulted in greater nutrient availability, which in turn led to greater nutrient uptake and increase in plant height, sympodial branches and drymatter accumulation This was earlier proved by Noori *et al.* (2018) [12] and Malik *et al*. (2021) [11].

Among the subplots, significantly higher plant height (180.8 cm), sympodial branches per plant (28.5), total dry matter accumulation (429.42 g plant^{-1}) was achieved when 0.6 per cent nano nitrogen was applied as foliar spray at three stages (S4) and it was followed by foliar application of 0.4 per cent nano nitrogen at three stages (S2) (173.3 cm), sympodial branches (28.0), dry matter accumulation (428.52 g plant^{-1}) which found *on par* with S4. The control plot, where no nano nitrogen sprayings were conducted, has recorded lower plant height of 155.5 cm, sympodial branches per plant (21.9), total dry matter buildup (384.18 g plant^{-1}). As nano particles have smaller size and larger surface area, its penetration and nutrient uptake is faster. Further these results are in conformity with the work of Burhan and Al-Hassan (2019) [4] and they reported that foliar application of nano fertilizers, results in faster nutrient uptake by amplifying the translocation of assimilate results in increased growth parametres like plant height, sympodial branches and total dry matter accumulation.

3.2 Seed cotton yield

Application of 100 per cent recommended dose of nitrogen (M3) recorded significantly higher seed cotton yield (3388 kg ha^{-1}), which was comparable to 75 per cent recommended dose of nitrogen (M2) (3376 kg ha^{-1}) which found *on par* with each other. On the other hand, application of 50 per cent recommended dose of nitrogen (M1) recorded significantly lower seed cotton yield (3080 kg ha^{-1}) (Table 1). Nitrogen is a key nutrient for plant growth and the increasing levels of nitrogen supplies the nutrients for reproductive growth parts and thus enhanced the seed cotton yield progressively. This was earlier proved by Alur *et al.* (2020) [3] and Malakannavar *et al.* (2019) [10].

Among sub plot treatments, foliar application of 0.6 per cent nano nitrogen at three stages (S4) recorded significantly higher seed cotton yield (3485 kg ha^{-1}) and it was followed by 0.4 per cent nano nitrogen at three stages (S2) (3465 kg ha^{-1}) which found *on par* with S4. The control plot (S5), which did not receive nano nitrogen spraying has recorded significantly lower seed cotton yield (3024 kg ha^{-1}). Nano form of nitrogen is more easily absorbed by the plants. The foliar application of nano nitrogen also helps to increase the photosynthetic rate of the plants, which can lead to increased boll production and thus enhanced seed cotton yield. Dhaliwal *et al*. (2021) [5] and Hemanth *et al*. (2022) [6] also reported that potential of the foliar application of nano form fertilizers resulted in significantly higher yield.

3.3 Economics of cotton Cost of cultivation (Rs. ha^{-1})

Increased nitrogen levels resulted in higher cultivation costs. The combination of 100 per cent nitrogen dosage with a 0.6 per cent nano nitrogen foliar treatment (M3S4) resulted in higher cost of cultivation (Rs.83,838 ha^{-1}). Lower cost of cultivation was recorded at lower levels of nutrient application *i.e.* at application of 50 per cent nitrogen application along with 0.4 per cent nano nitrogen foliar application at two stages (M1S5) (Rs.79,153 ha^{-1}) (Table 2.).

Gross returns and Net returns

Among main plot treatments, significantly higher gross returns

(Rs.2,71,024 ha^{-1}) and net returns (Rs.1,88,736 ha^{-1}) was obtained with the application of 100 per cent recommended dose of nitrogen (M3) and it was followed by 75 per cent recommended dose of nitrogen (M2) (Rs.2,70,112 ha^{-1}) and net returns (Rs.1,88,291 ha^{-1}) which found *on par* with M3. On the other hand, application of 50 per cent recommended dose of nitrogen (M1) recorded significantly lower gross returns (Rs.2,46,405 ha^{-1}) and net returns (Rs.1,65,052 ha^{-1}) (Table 2). Consequently, higher levels of nutrient application result in higher yields, leading to higher gross returns when compared to situations with lower levels of nutrient application. These findings and the results were in agreement of Malakannavar *et al.* (2021) [9] concluding that the application of 100 per cent recommended nutrients (100:50:50 kg NPK ha^{-1}) resulted in significantly higher gross returns as compared to 80 per cent RDF and 60 per cent RDF. Similar results were also attained by Kumar *et al.* (2022) [8] and they observed that nitrogen applied up to 225 kg ha^{-1} brought about progressive and significant improvement in gross returns and gave 43.66 per cent higher gross return over no N application.

Among sub plot treatments, foliar application of 0.6 per cent nano nitrogen at three stages (S4) resulted in significantly higher gross returns (Rs.2,78, 784 ha^{-1}) and net returns (Rs.1,95,414 ha^{-1}) and it was followed by 0.4 per cent nano nitrogen at three stages (S2) gross returns (Rs.2,77,238 ha^{-1}) and net returns (Rs.1,94,768 ha^{-1}) which found *on par* with S4. The control plot (S5) without nano nitrogen spraying has recorded significantly lower gross returns of Rs.2,41,955 ha^{-1} and net returns (Rs.1,62,335 ha^{-1}). Velmurugan *et al.* (2021) [14] stated that nano spray recorded higher yield over RDF addition resulting in gross returns. Further, the increased efficiency of nano urea resulted in saving of nitrogen fertilizer to the extent of 25-34 per cent.

BC ratio

Among main plot treatments, application of 75 per cent recommended dose of nitrogen (M2) resulted in significantly higher BC ratio (3.30) and it was followed by 100 per cent recommended dose of nitrogen (M3) (3.29). While application of 50 per cent recommended dose of nitrogen (M1) recorded significantly lower BC ratio (3.03). Malik *et al.* (2021) [11] also reported that increasing levels of nitrogen doses resulted in higher BC ratio ((Table 2).

Among sub plot treatments, foliar application of 0.4 per cent nano nitrogen at three stages (S2) (3.36) recorded significantly higher BC ratio and it was followed by 0.6 per cent nano nitrogen at three stages (S4) (3.34). The control plot (S5) without nano nitrogen spraying has recorded significantly lower BC ratio (3.04). Similar report was attained by Kanjana *et al.* (2020) 7[] and they stated that nano fertilizers performance was better on increasing the seed cotton yield and application of nano fertilizers has recorded significantly higher BC ratio in cotton.

4. Conclusion

Application of 75 per cent of the recommended nitrogen dose along with 0.4 per cent nano nitrogen foliar spray at three growth stages was observed to be effective and optimum for efficient nitrogen management in Bt cotton. The combined use of conventional nitrogen (75% RDN) and foliar application of nano nitrogen at flowering, boll initiation and boll development stages improved nutrient absorption, thereby enhancing yield and yield attributes of Bt cotton. Foliar spraying of nano nitrogen enabled a 25 per cent reduction in conventional fertilizer application. The integrated application of conventional nitrogen and nano nitrogen spray resulted in higher net returns and was found to be economically viable.

Table 1: Effect of different doses of nitrogen and foliar sprays of nano nitrogen on growth paramtres and yield of *Bt* cotton

Treatment	Plant height (cm)	No. of sympodial branches	Dry matter production (g plant^{-1})	Seed cotton yield (kg ha^{-1})
Main plot: Different dosages of nitrogen				
M1	162.5	23.3	376.41	3080
M2	168.0	26.7	426.91	3376
M3	176.9	27.1	430.31	3388
S. Em.±	3.1	0.6	2.68	59
C.D. at 5%	12.3	2.4	10.52	230
Sub plot: Different dosages of nano nitrogen				
S1	166.2	23.8	402.55	3148
S2	173.3	28.0	428.52	3465
S3	169.9	26.4	411.37	3284
S4	180.8	28.5	429.42	3485
S5	155.5	21.9	384.18	3024
S. Em.±	3.5	0.9	4.09	96
C.D. at 5%	10.1	2.5	11.93	281

Table 2: Effect of different doses of nitrogen and foliar sprays of nano nitrogen on economics of *Bt* cotton

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	BC ratio
Main plot: Different dosages of nitrogen				
M1	-	246405	165052	3.03
M2	-	270112	188291	3.30
M3	-	271024	188736	3.29
S. Em.±	-	5005	5005	0.06
C.D. at 5%	-	19652	19652	0.24
Sub plot: Different dosages of nano nitrogen				
S1	-	251875	170355	3.09
S2	-	277238	194768	3.36
S3	-	262714	180594	3.20
S4	-	278784	195414	3.34
S5	-	241955	162335	3.04
S. Em.±	-	4572	4572	0.06
C.D. at 5%	-	13346	13346	0.16

Main plots (M)

M1: 50% of recommended N kg ha^{-1}; M2: 75% of recommended N kg ha^{-1}; M3:100% of recommended N kg ha^{-1}.

Sub plots (S)

S1: Spraying of 0.4% nano nitrogen at flowering & boll initiation stages;

S2: Spraying of 0.4% nano nitrogen at flowering, boll initiation & boll development stages; S3: Spraying of 0.6% nano nitrogen at flowering & boll initiation stages;

S4: Spraying of 0.6% nano nitrogen at flowering, boll initiation & boll development stages; S5: Control (without spraying).

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