Evaluation of the effect of Urea and Nanourea on growth pattern of rainfed*Bt* Cotton (*Gossypiumhirsutum* L.)

Abstract

A field experiment was conducted to evaluate the effect of different levels of nitrogen through Nanourea and commercial urea with different time of nitrogen application on *Bt* Cotton (*Gossypiumhirsutum* L.)Fifteen treatment combinations consisting of five different levels of nitrogen through nano urea and commercial urea such as (125% of RDN through nano urea, 100% of through nano urea, 75% RDN through nano urea, 100% RDN through commercial urea and control plot (No nitrogen))were applied in threesplit applications of nitrogen at 30,60,90 DAS (40%,40%,20%), 30,60,90,120 DAS (25%,25%,25%,25%), 30,60,90,120 DAS (30%, 30%,20%,20%)were evaluated in split plot design with three replications. The highest absolute growth rates (AGR) for both plant height and dry matter in the context of application of nitrogen through commercial urea were observed during specific growth intervals: 61-90 days after sowing (DAS) for plant height (1.350 cm day^{-1} $plant^{-1}$) and 91-120 DAS for dry matter (2.374 g day^{-1} $plant^{-1}$).Similarly, when considering split application of nitrogen, the application of nitrogen at 30,60,90 DAS (40%,40%,20%) showed the highest AGR for plant height (1.054 cm day^{-1} $plant^{-1}$) during 61-90 DAS and for dry matter (2.158 g day^{-1} $plant^{-1}$) during 91-120 DAS. Furthermore, various growth parameters such as CGR, RGR, NAR, and LAI also exhibited their maximum values under both different levels of nitrogen and the mentioned split application of nitrogen.

Keywords: *Bt* cotton, levels of Nitrogen, Time of application,Foliar application, Soil application, LAI, NAR

Introduction

Cotton is one of the most important fiber and cash crop of India and plays a dominant role in the industrial and agricultural economy of the country. India plays a vital role in the global cotton landscape, accounting for around 21 per cent of the total cotton production, cultivated across 130.49 lakh hectares, which is estimated around 40 per cent of the world cotton area. At global level, although India occupies 40 per cent of the area, but contributes to mere 21 per cent of the global cotton production. And productivity of 439 kg ha^{-1}, as compared to leading cotton-producing countries like 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 USA (1061 kg ha^{-1}) (Anon, 2022). Maharashtra secure first position in area as well as its production in country which covers an area of 42.12 lakh ha with production of 107.55 lakh bales with an productivity of 398 kg lint ha-1 (Anonymous2018-19). It is cultivated in India from subHimalayanregion of Punjab in the north to Tamil Nadu in south and from dry regions of Kutch to high rainfall areas of Manipur in east. Major states cultivating cotton are Maharashtra, Gujarat, Andhra Pradesh, Karnataka, Madhya Pradesh, Punjab, Rajasthan, Haryana, Tamil Nadu and Uttar Pradesh. Nano urea as foliar spray in small quantities helps in easy absorption of nitrogen through stomata, improves crop growth, yield and reduce production costs. Higher productivity of crops in sustainable manner could be achieved applying appropriate combination of conventional fertilizer and nano fertilizers,it is proposed to reduce the application of conventional fertilizers by 25 per cent. Combined application of conventional and foliar application of nano nitrogen helps in obtaining higher seed cotton yield, net returns and found economically feasible. The hypothesis is

Material and Method

A field experiment was conducted in the *Kharif* season of 2021-22 at the AICRP on dryland farming in VasantraoNaikMarathwadaKrishiVidyapeeth, Parbhani, Maharashtra (India). The purpose was to assess the impact of Nanoureavis a avis commercial urea in cotton cultivation. The soil at the site was clayey, slightly alkaline (pH 8.0), low in salt content (0.30 dSm^{-1}), and had a high calcium carbonate content (45.88 g kg^{-1}) during the cropping season. The soil had 5.42 g kg^{-1} of organic carbon, low available nitrogen (174.53 kg ha^{-1}), medium available phosphorus (12.64 kg ha^{-1}), and very high available potassium (540.45 kg ha^{-1}) in the 2021-22 season. “In total, fifteen treatment combinations were tested,involving five different levels of nitrogen (125% RDF of N through Nano urea,100% RDF of N through Nano urea, 75% RDF of N through Nano urea,Control Plot (No Nitrogen) and 100% RDF of N through Urea) Nitrogen was applied inthreesplit application of nitrogen (30, 60, 90 DAS (20%, 40%, 40%), 30, 60, 90, 120 DAS (25%, 25%, 25%, 25%), 30, 60, 90, 120 DAS (20%, 30%, 30%, 20%)). The experiment was laid out in split-plot design with three replications. Before cotton sowing, *Rabi* sorghum was cultivated in the field, harvested in March, and the field was left fallow. Cotton variety AJIT-1155 was sown on June 28, 2021, with at 120 X 45 cm, respectively, resulting in a plant population of 18,500 plants per hectare. Sowing was done manually by dibbling with a 45 cm plant spacing". "Well-decomposed farmyard manure (FYM) was uniformly applied to the plots before sowing according to the treatment specifications. Fertilizers such as nanourea and commercial urea were applied based on the treatments. Phosphorus and Potassium applied as a basal dose at sowing. Fertilizers were applied through Nanourea (4% N), Urea (46% N), single superphosphate (16% P_2O_5),and muriate of potash (60% K_2O) were used as nutrient sources for nitrogen, phosphorus, and potassium, respectively". Data on various growth parameters were collected at 30-day intervals from the sowing date until harvest.Different growth rates were calculated using specific formulas given below.

2.1 Absolute Growth Rate (AGR)

The absolute growth rate (AGR) of a specific plant characteristic, such as height (H) or dry weight (W), during a particular time interval (t), is a measure of how fast it is growing. This rate is typically expressed as centimetres per day for plant height and grams per day for the accumulation of dry matter in each plant. The formula used to calculate the AGR for both plant height and total dry matter per plant was developed by Blackman (1919). Now it is called as classical growth analysis.

$$\text{AGR (Height) (cm day}^{-1}\text{)} = H_2 – H_1 / t_2 – t_1$$

$$\text{AGR (Dry matter) (g day}^{-1}\text{)} = W_2 – W_1 / t_2 – t_1$$

Where,

H_2 and H_1 are plant heights, while W_2 and W_1 are dry matter weights per plant at t_2 and t_1 times, respectively.

2.2 Crop Growth Rate (CGR)

It is the rate of increase of dry weight per unit land area per unit time.Watson (1958) suggested the following formula to arrive Crop Growth Rate

$$\text{CGR (g day}^{-1}\text{ m}^{-2}\text{)} = (W_2 – W_1 / t_2 – t_1) \text{ x number of plants m}^{-2}$$

Where,

W_2 = dry weight of plant at time t_2 (g plant^{-1})

W_1 = dry weight of plant at time t_1 (g plant^{-1})

3.8.3 Relative growth rate (RGR)

Blackman (1919) pointed out that the increase in dry matter of plant is a process of continuous compound interest wherein the increment in any interval adds to the capital for the subsequent crop growth. This rate of increment is known as relative growth rate (RGR), which was worked out by the formula given by Fisher (1921).

$$RGR\ (gg^{-1}\ day^{-1}) = \frac{Log_e W_2 - Log_e W_1}{t_2 - t_1}$$

Where,

W_1 and W_2 are the weights of dry matter in g per plant at times t_1 and t_2, respectively and t_2- t_1 is the time interval in days.

Log_e = natural logarithm to the base 'e' = 2.3026.

3.8.4 Net assimilation rate (NAR)

Gregory (1917) introduced the concept of net assimilation rate (NAR) to obtain simple growth measurement as an estimate of the assimilatory efficiency of leaves. It is the rate of increase in whole plant dry weight per unitleaf area. It indicates rate of net photosynthesis and is expressed as [23]

$$NAR\ (gdm^{-2}\ day^{-1}) = \frac{(W_2 - W_1)(Log_e A_2 - Log_e A_1)}{(t_2 - t_1)(A_2 - A_1)}$$

Where,

W_2 = dry weight of plant at time t_2 (g plant^{-1})

W_1 = dry weight of plant at time t_1 (g plant^{-1})

A_2 = leaf area plant^{-1} at time t_2 (dm^2)

A_1 = leaf area plant^{-1} at time t_1 (dm^2)

Log_e = natural logarithm to the base 'e' = 2.3026

3.8.5 Leaf area index (LAI)

Leaf area ratio is the ratio of surface leaf area (one side only) to the ground area occupied by the crop plant. Crop yield in general is assessed based on per unit of ground area instead of per plant. The leaf area index was determined by using the formula given by Watson (1952).

$$\text{LAI} = \frac{\text{Leaf area per plant (dm}^2\text{)}}{\text{Ground area per plant (dm}^2\text{)}}$$

3. RESULTS

The results of the present study have been summarised under following heads.

3.1 Absolute Growth Rate (AGR) for Plant Height (cm day^{-1} plant^{-1})

Plant height was maximum under 100% RDF of nitrogen through commercial urea(S_5), followed by 125% RDF of N through Nano urea (S_1). between days 61 and 90 after sowing, 100% RDF of nitrogen through commercial urea (S_5) resulted in the highest growth rate of 1.354 cm per day, while Control plot (S_4) only reached 0.753 cm per day. Between days 61 and 90 after sowing, the highest growth rate of 1.053 cm per day was observed under the split application of nitrogen at 30,60,90 DAS (40%, 40%, 20%) (T_1), while 30,60,90,120 DAS (20%, 30%, 30%, 20%) (T_3) had the lowest growth rate during the same growth interval, with only 1.014 cm per day.

3.2 Absolute Growth Rate (AGR) for Dry Matter (g day^{-1} plant^{-1})

Different levels of nitrogen had an impact on the mean absolute growth rate (AGR) of dry matter (in grams per day per plant) in *Bt* cotton (Table 1). The data clearly indicate that the highest AGR values were consistently observed in the case of 100% RDF of nitrogen through commercial urea (S_5) across all growth stages, followed by 125% RDF of N through Nano urea (S_1). Specifically, during the 91-120 days after sowing (DAS) period, the highest AGR value of 2.375 grams per day per plant was recorded under 100% RDF of nitrogen through commercial urea (S_5), while control plot (no nitrogen) (S_4) had a lower value of 1.445 grams per day per plant during the same growth interval. During the 91-120 DAS period, the highest mean AGR value of 2.049 grams per day was recorded under split application of nitrogen at 30,60,90 DAS (40%, 40%, 20%) (T_1), while the split application of nitrogen at30, 60, 90, 120 DAS (25%, 25%, 25%, 25%)(T_2) had the lowest value of 1.788 grams per day during the same growth interval.

3.3 Crop Growth Rate (CGR) for Dry Matter (g day^{-1} m^{-2})

Application of 100% RDF of nitrogen through commercial urea (S_5) all growth stages from planting to harvest, with a peak CGR value of 4.394 g day^{-1} m^{-2}. On the other hand, control plot (no nitrogen)(S_4) consistently exhibited the lowest CGR, with a minimum value of 2.674 g day^{-1} m^{-2} recorded between 91-120 days after sowing. The highest mean CGR value of 3.790 g day^{-1} m^{-2} was recorded between 91-120 days after sowing under the split application of nitrogen at 30,60,90 DAS (40%, 40%, 20%) (T_1), while the split application of nitrogen at30, 60, 90, 120 DAS (25%, 25%, 25%, 25%)(T_2)exhibited the lowest CGR value of 3.308 g day^{-1} m^{-2} during the same growth interval.

3.4 Relative Growth Rate (RGR) for Dry Matter (g g^{-1} day^{-1})

Maximum RGR value, 0.0927g g^{-1} day^{-1}, was observedwith application of 100% RDF of nitrogen through commercial urea (S_5), whereas control plot (no nitrogen)(S_4)had the lowest RGR value of 0.0791g g^{-1} day^{-1} between 31-60 days after sowing (DAS). Nitrogen applied at 30,60,90 DAS (40%, 40%, 20%) (T_1) resulted in the highest RGR values across all growth intervals. This was followed by the treatment of four split application of nitrogen at with 30,60,90,120 DAS (20%, 30%, 30%, 20%) (T_3), as well as the foursplit application of nitrogen at30, 60, 90, 120 DAS (25%, 25%, 25%, 25%)(T_2). The peak mean RGR value of 0.0865g g^{-1} day^{-1} occurred between 31-60 DAS.four split application of nitrogen at30, 60, 90, 120 DAS (25%, 25%, 25%, 25%)(T_2) had the lowest RGR value of 0.0842g g^{-1} day^{-1} during the same growth interval.

3.5 Net Assimilation Rate (NAR) (g dm^{-2} day^{-1})

The maximum NAR value of 0.0563g dm^{-2} day^{-1} was observed under application of 100% RDF of nitrogen through commercial urea (S_5), whereas control plot (no nitrogen)(S_4) recorded the lowest NAR value of 0.0462g dm^{-2} day^{-1} between 31-60 days after sowing (DAS). Application of nitrogen, at 30,60,90 DAS (40%, 40%, 20%) (T_1) resulted in the highest NAR values across all growth intervals. This was followed by split application of nitrogen at with 30,60,90,120 DAS (20%, 30%, 30%, 20%) (T_3)and the split application of nitrogen at30, 60, 90, 120 DAS (25%, 25%, 25%, 25%)(T_2). The peak mean NAR value of 0.0514 g dm^{-2} day^{-1} occurred between 31-60 DAS with the the split application of nitrogen at 30,60,90 DAS (40%, 40%, 20%) (T_1), while the split application of nitrogen at30, 60, 90, 120 DAS (25%, 25%, 25%, 25%)(T_2)recorded the lowest value of 0.0452 g dm^{-2} day^{-1} during the same growth interval.

3.6 Leaf Area Index (LAI)

Application of 100% RDF of nitrogen through commercial urea (S_5) resulted in the highest LAI value of 3.106, while control plot (no nitrogen)(S_4) had the lowest value of 1.567 during the period from 91 to 120 days after sowing (DAS). Application of nitrogen at 30,60,90 DAS (40%, 40%, 20%) (T_1) consistently led to the highest LAI values at all growth intervals. This was followed by the treatment involving split application of nitrogen at with 30,60,90,120 DAS (20%, 30%, 30%, 20%) (T_3). The highest LAI value of 2.649 was observed under the split application of nitrogen at 30,60,90 DAS (40%, 40%, 20%) (T_1), while the split application of nitrogen at30, 60, 90, 120 DAS (25%, 25%, 25%, 25%)(T_2)recorded the lowest LAI value of 2.398 at 120 DAS.

4. DISCUSSION

Different levels of nitrogen through nanourea and commercial urea might be attributed to higher nutrient supply which enhanced the growth of plants, by participating in cell division and cell elongation in plants. It was corelated with the increase in various crop growth attributes including their height, dry matter and leaf area which has contributed to higher accumulation of plant dry matter". Consequently, the increased plant height and dry matter accumulation have led to higher rates of growth. The improved growth rates observed when using Application of 100% RDF of nitrogen through commercial urea (S_5) can be attributed to the increased supply of nutrients. These nutrients play a vital role in promoting plant growth by supporting cell division and elongation in plants. The split application nitrogen have increased theavailabilityof nitrogenthat enhanced the crop growth. The improved plant growth contributed to better partitioning of assimilates intoThese improvements are closely associated with various aspects of crop growth, including plant height, leaf area, and the accumulation of dry matter. Consequently, the greater plant height increased dry matter accumulation contribute to overall higher growth rates.

5. CONCLUSION

The highest plant height and dry matter accumulation were observed with application of 100% RDF of nitrogen through commercial urea applied in splits at 30,60,90 DAS (40%, 40%, 20%).Additionally, the mean crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), and leaf area index (LAI) were all at their maximum levels under the same treatment of application of 100% RDF of nitrogen through commercial urea with the split application of nitrogen at 30,60,90 DAS (40%, 40%, 20%).

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Details of the AI usage are given below:

1.

2.

3.

Table 1. Mean AGR for plant height (cm day^{-1} plant^{-1}) and for dry matter (g day^{-1} plant^{-1}) of *Bt* cotton hybrid as influenced by Different levels of nitrogen and time of application of nitrogen.

Treatment	Mean Absolute Growth Rate (AGR) for plant height(cm day^{-1} plant^{-1})						Mean Absolute Growth Rate (AGR) for dry matter (gm day^{-1} plant^{-1})					
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**150 DAS**	**At Harvest**	**30 DAS**	**60 DAS**	**90 DAS**	**120 DAS**	**150 DAS**	**At Harvest**
A) Main plot treatment (Different levels of nitrogen)												
S_1-125% RDF of Nthrough Nanourea	0.731	0.974	1.164	0.628	0.379	0.123	0.122	1.036	1.265	2.132	0.247	-0.655
S_2- 100% RDF of Nthrough Nano urea	0.714	0.914	1.002	0.559	0.322	0.101	0.120	0.913	1.219	1.938	0.238	-0.615
S_3- 75% RDF of Nthrough Nano urea	0.692	0.837	0.985	0.518	0.308	0.080	0.118	0.809	1.096	1.650	0.174	-0.601
S_4- Control Plot(no Nitrogen)	0.649	0.711	0.749	0.473	0.296	0.070	0.113	0.705	0.994	1.445	0.160	-0.586
S_5-RDF of Nthrough commercial urea	0.794	1.183	1.354	0.742	0.474	0.130	0.128	1.178	1.587	2.375	0.309	-0.892
B) Sub plot treatment (Time of application of nitrogen)												
T_1- 30, 60, 90 DAS (20%, 40%, 40%)	0.738	0.945	1.049	0.634	0.456	0.115	0.131	1.020	1.381	2.049	0.328	-0.815
T_2- 30, 60, 90, 120 DAS (25%, 25%, 25%, 25%)	0.714	0.870	1.036	0.562	0.407	0.081	0.115	0.827	1.158	1.788	0.158	-0.617
T_3- 30, 60, 90, 120 DAS (20%, 30%, 30%, 20%)	0.723	0.915	1.025	0.612	0.418	0.099	0.123	0.931	1.158	1.887	0.198	-0.654
General mean	**0.723**	**0.910**	**1.034**	**0.587**	**0.383**	**0.100**	**0.121**	**0.930**	**1.232**	**1.915**	**0.230**	**-0.685**

Table 2. Mean CGR (g day^{-1} m^{-2}) and mean RGR (g g^{-1} day^{-1}) of *Bt* cotton hybrid as influenced by Different levels of nitrogen and time of application of nitrogen.

Treatment	Mean Absolute Growth Rate (CGR) for plant height(cm day^{-1} plant^{-1})						Mean Absolute Growth Rate (RGR) for dry matter (gm day^{-1} plant^{-1})					
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	At Harvest	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	At Harvest
A) Main plot treatment (Different levels of nitrogen)												
S_1-125% RDF of Nthrough Nanourea	0.226	1.917	2.341	3.944	0.456	-1.212	0.0520	0.0899	0.0315	0.0245	0.0020	-0.0059
S_2- 100% RDF of Nthrough Nano urea	0.223	1.688	2.255	3.585	0.440	-1.138	0.0513	0.0859	0.0305	0.0240	0.0018	-0.0068
S_3- 75% RDF of Nthrough Nano urea	0.219	1.497	2.028	3.053	0.321	-1.111	0.0506	0.0823	0.0300	0.0238	0.0016	-0.0068
S_4- Control Plot(no Nitrogen)	0.209	1.304	1.838	2.674	0.296	-1.085	0.0488	0.0791	0.0298	0.0234	0.0014	-0.0055
S_5-RDF of Nthrough commercial urea	0.237	2.180	2.937	4.394	0.572	-1.650	0.0539	0.0927	0.0328	0.0252	0.0022	-0.0075
B) Sub plot treatment (Time of application of nitrogen)												
T1- 30, 60, 90 DAS (20%, 40%, 40%)	0.242	1.886	2.555	3.790	0.607	-1.508	0.0547	0.0888	0.0350	0.0257	0.0028	-0.0073
T2- 30, 60, 90, 120 DAS (25%, 25%, 25%, 25%)	0.212	1.530	2.142	3.308	0.292	-1.141	0.0494	0.0842	0.0296	0.0246	0.0011	-0.0061
T_3- 30, 60, 90, 120 DAS (20%, 30%, 30%, 20%)	0.227	1.722	2.142	3.492	0.366	-1.211	0.0497	0.0863	0.0320	0.0247	0.0019	-0.0063
General mean	**0.224**	**1.715**	**2.279**	**3.530**	**0.418**	**-1.257**	**0.0513**	**0.0865**	**0.0311**	**0.0243**	**0.0020**	**-0.0066**

Table 3. Mean NAR (g dm^{-2} day^{-1}) and Mean LAIof *Bt* cotton hybrid as influenced by Different levels of nitrogen and time of application of nitrogen.

Treatment	Mean Net Assimilation Rate (NAR) (g dm^{-2} day^{-1})						Mean Leaf Area Index (LAI)					
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	At Harvest	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	At Harvest
A) Main plot treatment (Different levels of nitrogen)												
S_1-125% RDF of Nthrough Nanourea	0.731	0.974	1.164	0.628	0.379	0.123	0.122	1.036	1.265	2.132	0.247	-0.655
S_2- 100% RDF of Nthrough Nano urea	0.714	0.914	1.002	0.559	0.322	0.101	0.120	0.913	1.219	1.938	0.238	-0.615
S_3- 75% RDF of Nthrough Nano urea	0.692	0.837	0.985	0.518	0.308	0.080	0.118	0.809	1.096	1.650	0.174	-0.601
S_4- Control Plot(no Nitrogen)	0.649	0.711	0.749	0.473	0.296	0.070	0.113	0.705	0.994	1.445	0.160	-0.586
S_5-RDF of Nthrough commercial urea	0.794	1.183	1.354	0.742	0.474	0.130	0.128	1.178	1.587	2.375	0.309	-0.892
B) Sub plot treatment (Time of application of nitrogen)												
T1- 30, 60, 90 DAS (20%, 40%, 40%)	0.738	0.945	1.049	0.634	0.456	0.115	0.131	1.020	1.381	2.049	0.328	-0.815
T2- 30, 60, 90, 120 DAS (25%, 25%, 25%, 25%)	0.714	0.870	1.036	0.562	0.407	0.081	0.115	0.827	1.158	1.788	0.158	-0.617
T_3- 30, 60, 90, 120 DAS (20%, 30%, 30%, 20%)	0.723	0.915	1.025	0.612	0.418	0.099	0.123	0.931	1.158	1.887	0.198	-0.654
General mean	**0.723**	**0.910**	**1.034**	**0.587**	**0.383**	**0.100**	**0.121**	**0.930**	**1.232**	**1.915**	**0.230**	**-0.685**

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