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**Research Paper**

# Productivity, nutrient uptake and nitrogen–use efficiency of Bt. cotton (*Gossypium hirsutum*) in relation to split and foliar application of nitrogen on Inceptisol

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## ABSTRACT

A 2-years field experiment was carried out at Rahuri from 2011 to 2012 on an Inceptisol soil having 147 kg/ha available N, to study productivity, nutrient uptake and nitrogen-use efficiency of Bt. Cotton (*Gossypium hirsutum* L.) as affected by split and foliar application of nitrogen. In Bt. Cotton, 10 treatments comprising nitrogen–management practices (application of recommended dose of N in 3, 4, 5, 6 splits; foliar application of 20 g $KNO_3$/litre water, 20 g urea/litre water, combination of split application of N and foliar spray of 20 g $KNO_3$/litre water, 20 g urea/litre water and control) were tested on inceptisol. Results indicated that application of N in six splits (20% at sowing as basal and remaining in 5 equal splits at 30, 45, 60, 75 and 90 DAS) recorded significantly higher plant height, sympodial branches/plant, dry-matter/plant, bolls/plant, seed cotton yield/plant, seed cotton yield (66% more than control), higher gross, net monetary returns, benefit: cost ratio, higher uptake of nutrients (N, P and K) and higher agronomic nitrogen–use efficiency. N application in 3 equal splits (at sowing, 30 and 60 DAS + foliar application of 20 g $KNO_3$/litre water at 60, 75 and 90 DAS) recorded significantly higher boll weight. The physiological nitrogen–use efficiency was found higher with the N application in 3 equal splits (at sowing, 30 and 60 DAS + foliar application of 20g urea/litre water at 60, 75 and 90 DAS).

***Key words :*** Bt. cotton, Foliar nutrition, N use efficiency, Nutrient uptake, Split nitrogen application

Cotton is the world's leading fibre crop and the second most important oilseed crop. After China, India accounts for about 32% of the global cotton area and contributes 21% of the global cotton production (Venugopalan *et al.,* 2012 a). Maharashtra ranks first in acreage with 4.09 million ha and second in production yielding 6.9 million bales next to Gujarat (11.4 million bales) with average productivity of 379 kg lint/ ha, which is low as compared to national average of 512 kg/ha (AICCIP, 2012).

The incorporation of *Bacillus thuriengensis* bacteria in cotton has changed the crop morphology, phenology, physiology and translocation efficiency of photosynthtes into the bolls (Chen *et al.,* 2002). Kefyalew *et al.* (2007) reported that the replacement of old cultures of cotton with transgenic removed the pressure of boll weevils and thereby changed the yield potential. This has driven increased nutrient uptake especially of nitrogen. Therefore, new agronomic management practices need to be developed.

A major component of profitable cotton production is adequate and balanced nutrition. Sound cotton fertilization practices ensure improved economics of production, efficiency of nutrient use, and environmental protection. Nitrogen is the most essential nutrient for cotton plant growth, which needs to be supplied in proper time and quantities. Among N, P and K, the application of N alone was found essential for increasing yield. Both rainfed and irrigated cotton responds to nitrogen. The N application response was higher in the latter stages (Venugopalan *et al.,* 2012 b). Nitrogen supplement therefore by split application becomes important as it is supplied ideally in a time when crop critically requires. Bt. cotton differs in its requirement either by total or part of it in the different stage of crop. Thus, nitrogen–use efficiency can be increased and better used to attain the objective of higher production (Hallikeri *et al.*, 2011).

Major nutrients application through soil is a common practice for the supply of nutrients in irrigated cotton. Plants respond quickly to foliar nutrition of both major

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and micro-nutrients to supplement soil uptake and correct in-season nutrient deficiencies in plant parts. Foliar application of nutrients through fertilizers such as di ammonium phosphate (DAP), potassium chloride (KCl) and micronutrient mixtures during flower and boll-development stages have been shown to be effective in efficient utilization of nutrients by cotton and thereby reduce boll shedding and increase the yield. Foliar fertilization can be used to improve the efficiency and rapidity of utilization of a nutrient urgently required by cotton crop for maximum growth and yield. However, foliar nutrition should only serve as a supplement to traditional soil applied fertilizer for a sufficient supply of nutrients to the developing cotton crop for optimum yields and fibre quality (Rajendran *et al.*, 2010). With this background in view, the present investigation was planned to determine the effect of split and foliar application of nitrogen on productivity, nutrient uptake and nitrogen use efficiency of Bt. cotton.

## MATERIALS AND METHODS

The present experiment was conducted at the Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra, India for successive 2 years (2011 and 2012), in randomized block design with 3 replications. The plot size was 6.3 m × 5.4 m. The soil of experimental plot was clay loam and slightly alkaline (pH 8.03), low in available nitrogen (147 kg/ha), medium in available phosphorus (16 kg/ha) and high in potassium content (482 kg/ha). The crop was fertilized with 125: 62.50: 62.50 kg NPK/ha + 10 t FYM/ha. The treatments consisted of $T_1$, N application in 3 equal splits at sowing, 30 and 60 Days after sowing (DAS); $T_2$, N application in 3 splits as 20, 40, 40% at sowing, 30 and 60 DAS; $T_3$, N application in 4 equal splits at sowing, 30, 45 and 60 DAS; $T_4$, N application in 5 equal splits at sowing, 30, 45, 60 and 75 DAS; $T_5$, N application in 6 splits as 20% at sowing and remaining in 5 equal splits at 30, 45, 60, 75 and 90 DAS; $T_6$, $T_1$+ foliar application of 20 g urea/litre water at 60, 75 and 90 DAS; $T_7$, $T_1$ + foliar application of 20 g $KNO_3$/litre water at 60, 75 and 90 DAS; $T_8$, $T_2$ + foliar application of 20 g urea/litre water at 60, 75 and 90 DAS; $T_9$, $T_2$ + foliar application of 20 g $KNO_3$/litre water at 60, 75 and 90 DAS and $T_{10}$, no nitrogen (Control). A uniform basal application of 62.50 kg $P_2O_5$ through single superphosphate and 62.50 kg $K_2O$/ ha through murate of potash was done in all the treatments. Nitrogen was applied through urea as per the treatments. For the foliar application of nutrients at 60 DAS, 100 litres water/ ha was used in which 2.0 kg urea and $KNO_3$ as per treatments was mixed and used as spray solution. At 75 and 90 DAS, 200 litres water/ha along with 4.0 kg urea and $KNO_3$ as per treatments was mixed and utilized as spray solution.

Two seeds of cotton 'BG-II' (NCS 207) were sown by dibbling with 90 cm × 45 cm geometry on 24 April 2011 and 26 April 2012. One healthy seedling/ hill was kept after thinning operation at 30 DAS. Three manual weedings were done to keep the crop free of weeds. Timely recommended plant-protection measures for irrigated cotton were followed to save the crop from pests and diseases. Immediately after sowing, surface irrigation was applied to cotton crop and the second irrigation was followed within 1 week of sowing to ensure the good germination. Subsequent irrigations were given to the cotton crop at vegetative, square initiation, flowering, boll formation and boll-development stages during both the years. The cotton crop was harvested in 3 pickings during both the years.

Different yield components, viz. plant height, sympodial branches, bolls/plant, seed-cotton yield/plant and boll weight (g), were recorded periodically. The seed-cotton weight of different pickings from net plot area were recorded treatment-wise and total seed-cotton yield/ha was calculated. The plant samples after recording observations were dried in oven at 65°C. The samples were made composite and after the grinding into fine powder, used for analysis of nitrogen, phosphorus and potassium content using micro Kjeldahls' method, vanadomolybdate yellow colour method and flame photometric method (Jackson, 1973). Nitrogen-use efficiencies were computed as follows with the formulae given by Choudhary and Behera (2013). Agronomic N-use efficiency (kg yield increase/kg N applied): $[(Y_t - Y_0)/ N_a]$ and Physiological N-use efficiency (kg yield increase/kg N uptake increase): $[(Y_t - Y_0)/ (U_t - U_0)]$, where $Y_t$: Yield in test treatment (kg/ha); $Y_0$: Yield in control plot; $N_a$: Units of N applied in the test treatment (kg/ha); $U_t$: Uptake of N in the test treatment (kg/ha) and $U_0$: Uptake of N in the control plot (kg/ha).

The data on various parameters recorded from experimental plot were statistically analysed as suggested by Panse and Sukhatme (1995) by using the randomized block design. Whenever results were found significant the critical difference (C.D.) values at 5 % level of probability were worked out.

## RESULTS AND DISCUSSION

### *Growth and yield parameters*

Split and foliar application of nitrogen significantly influenced the cotton plant height, sympodial branches, bolls/plant, dry-matter accumulation, seed cotton yield/ plant and boll weight (Table 1). Application of N in 6 splits (20% at sowing and remaining in 5 equal splits at 30, 45, 60, 75 and 90 DAS) recorded significantly higher plant height, sympodial branches, bolls/plant, dry-matter accumulation and seed-cotton yield/plant compared to the other treatments. Nitrogen plays an important role in multiplication of cells and formation of plant parts, which resulted in higher growth of cotton. Cotton being an indeterminate crop having long duration, timely supply of N under split application might have increased sympodial branches, bolls, dry-matter accumulation/plant, which resulted in higher seed-cotton yield/plant. Split application of nitrogen encourages more dry-matter accumulation and finally resulted into better yield (Srinivasan, 2003). Application of N at 0, 30, 45, 60, 75 and 90 DAS might have been congenial to meet the peak N requirement of Bt. cotton crop. The conventional methods ($T_1$ and $T_2$) might have failed to supply the required N at later stages, as the major portion of the applied N might have been lost through leaching and volatilization.

The important yield component boll weight was significantly influenced by foliar nutrition. Nitrogen application in 3 equal splits at sowing, 30 and 60 DAS + foliar application of 20 g $KNO_3$/litre water at 60, 75 and 90 DAS recorded significantly higher boll weight over rest of the treatments except treatment $T_9$ which was on a par with $T_7$. This could be attributed to the role of N and K. The positive effect of mineral nutrients supplied through $KNO_3$ on a number of sink organs results not only from an increase in mineral nutrient supply, but also an increase in the photosynthate supply to the sink sites (Borowski, 2001). Waraich *et al.* (2011) reported significantly higher boll weight with 3 foliar applications of 15 g $KNO_3$/litre water at flowering, second and third at 14 days interval than water sprays and control treatments in cotton. It has been proved that potassium deficiency results in early abscission of leaves and carbohydrates accumulation in main stem leaves, hence the top bolls of cotton plant develops incompletely, and boll weight was lowered in control and water spray treatments. Increase in boll weight with foliar application of $KNO_3$ is in agreement with results of Reddy *et al.* (2004) and Read *et al.* (2006).

### *Seed-cotton and cotton stalk yield*

Nitrogen application in 6 splits (20% at sowing and remaining in 5 equal splits at 30, 45, 60, 75 and 90 DAS) recorded significantly higher seed-cotton and stalk yield over all other treatments (Table 2). The lowest seed cotton and stalk yield were recorded with the control. Treatment $T_5$ recorded 25.58, 31.56 and 66.11% more yield than recommended practices ($T_1$ and $T_2$) and control respectively. Increase in the growth attributes and dry-matter accumulation, which is an index of higher photosynthetic capacity of plant, with the treatment $T_5$ improved the bolls/plant by enabling the plant to trap more solar radiation energy and the timely supply of nitrogen resulted in higher plant

**Table 1.** Growth and yield attributes of Bt. cotton as influenced by split and foliar application of nitrogen (mean data of 2 years)

| Treatment | | Plant height (cm) | Sympodial branches/ plant | Dry matter/ plant (g) | Bolls/ plant | Seed-cotton yield/plant (g) | Boll weight (g) |
|---|---|---|---|---|---|---|---|
| $T_1$, | N application in 3 equal splits at sowing, 30 and 60 Days after sowing (DAS) | 95 | 10.8 | 177 | 22.8 | 97.0 | 4.26 |
| $T_2$, | N application in 3 splits as 20, 40, 40% at sowing, 30 and 60 DAS | 95 | 10.8 | 175 | 21.9 | 92.0 | 4.28 |
| $T_3$, | N application in 4 equal splits at sowing, 30, 45 and 60 DAS | 102 | 12.6 | 188 | 29.5 | 124.2 | 4.28 |
| $T_4$, | N application in 5 equal splits at sowing, 30, 45, 60 and 75 DAS | 105 | 14.3 | 188 | 30.9 | 131.1 | 4.29 |
| $T_5$, | N application in 6 splits as 20% at sowing and remaining in 5 equal splits at 30, 45, 60, 75 and 90 DAS | 114 | 15.6 | 200 | 37.1 | 160.6 | 4.34 |
| $T_6$, | $T_1$+ foliar application of 20 g urea/litre water at 60, 75 and 90 DAS | 98 | 12.0 | 182 | 23.8 | 100.8 | 4.28 |
| $T_7$, | $T_1$ + foliar application of 20 g $KNO_3$/litre water at 60, 75 and 90 DAS | 100 | 12.8 | 187 | 26.1 | 117.8 | 4.51 |
| $T_8$, | $T_2$ + foliar application of 20 g urea/litre water at 60, 75 and 90 DAS | 98 | 10.9 | 181 | 22.6 | 96.5 | 4.31 |
| $T_9$, | $T_2$ + foliar application of 20 g $KNO_3$/litre water at 60, 75 and 90 DAS | 100 | 12.0 | 183 | 23.8 | 104.4 | 4.46 |
| $T_{10}$, | no nitrogen (Control) | 64 | 7.3 | 112 | 15.5 | 55.8 | 3.28 |
| | SEm$\pm$ | 2.4 | 0.3 | 3.1 | 0.8 | 3.5 | 0.03 |
| | CD (P=0.05) | 7.0 | 0.8 | 9.3 | 2.4 | 10.5 | 0.10 |

Details of treatments are given under materials and methods height, sympodial branches hence formation of more bolls. Dry-matter production followed similar trend as that of other growth attributes, viz. plant height and sympodial branches/plant. Split application of N improved these growth parameters and thus resulted in higher seed-cotton yield. The results are in agreement with findings of Alagudurai *et al.* (2006), Pandagale *et al.* (2012), Gokhale *et al.* (2012) and Gawade and Bhalerao (2012).

### *Economics*

Economics of Bt. cotton production was significantly influenced by the split and foliar application of nitrogen (Table 2). Application of N in 6 splits (20% at sowing and remaining in 5 equal splits at 30, 45, 60, 75 and 90 DAS) recorded significantly higher gross returns (₹ 32,540 and additional gross returns (₹40,060) over recommended practices $T_1$ and $T_2$ respectively) and net returns (₹22,660) and (₹29,260) additional net returns over recommended practices $T_1$ and $T_2$ respectively). The benefit: cost ratio was also higher with the treatment $T_5$. Increased yield owing to splitting of nitrogen significantly increased the gross and net monetary returns. The results confirm the findings of Raju *et al.* (2008) and Rajendran *et al.* (2012)

### *Nutrient uptake*

Nitrogen application in 6 splits (20% at sowing and remaining in 5 equal splits at 30, 45, 60, 75 and 90 DAS) recorded significantly higher uptake of nitrogen (221.6 kg/ha) over all other treatments (Table 3). This treatment has also recorded significantly higher uptake of phosphorus, but it was on par with rest of the treatments except treatment $T_2$ and control. Treatment $T_5$ also recorded significantly higher uptake of potassium over the rest of the treatment except treatment $T_7$ and treatment $T_{9,}$ which were at par with treatment $T_5$. The lowest uptake of nutrients was recorded with the control. Nutrient uptake by cotton is directly related to dry-matter accumulation, timely supply of nitrogen under the treatment $T_5$ to the plant throughout the growth period resulted in higher dry-matter production, which reflected into higher uptake of nutrients. These results are in accordance with the findings of Srinivasan (2003), Raju *et al.* (2008), Das and Reddy (2009)

### *Agronomic and physiological N-use efficiency*

Application of N in 6 splits (20% at sowing and remaining in 5 equal splits at 30, 45, 60, 75 and 90 DAS) recorded significantly higher agronomic N-use efficiency (Table 3), whereas treatment N application in 3 splits as 20, 40, 40% at sowing, 30 and 60 DAS recorded the lowest agronomic N-use efficiency. This might be due to the N supplied in 6 splits ideally in a time when crop critically required and also the N losses via leaching, denitrification

**Table 2**. Yield and economics of Bt. cotton as influenced by split and foliar application of nitrogen (mean data of 2 years)

| Treatment | Seed-cotton yield (t/ha) | Stalk yield (t/ha) | Cost of cultivation (×10³₹/ha) | Gross returns (×10³₹/ha) | Net returns (×10³₹/ha) | Benefit: cost ratio |
|---|---|---|---|---|---|---|
| $T_1$, N application in 3 equal splits at sowing, 30 and 60 Days after sowing (DAS) | 2.24 | 8.06 | 61.23 | 94.86 | 33.64 | 1.55 |
| $T_2$, N application in 3 splits as 20, 40, 40% at sowing, 30 and 60 DAS | 2.06 | 7.94 | 60.31 | 87.34 | 27.04 | 1.45 |
| $T_3$, N application in 4 equal splits at sowing, 30, 45 and 60 DAS | 2.58 | 8.17 | 64.98 | 108.63 | 43.65 | 1.67 |
| $T_4$, N application in 5 equal splits at sowing, 30, 45, 60 and 75 DAS | 2.76 | 9.65 | 67.81 | 116.41 | 48.60 | 1.72 |
| $T_5$, N application in 6 splits as 20% at sowing and remaining in 5 equal splits at 30, 45, 60, 75 and 90 DAS | 3.01 | 10.59 | 71.10 | 127.40 | 56.30 | 1.79 |
| $T_6$, $T_1$+ foliar application of 20 g urea/litre water at 60, 75 and 90 DAS | 2.54 | 8.39 | 63.54 | 107.03 | 43.49 | 1.68 |
| $T_7$, $T_1$ + foliar application of 20 g $KNO_3$/litre water at 60, 75 and 90 DAS | 2.57 | 9.09 | 64.93 | 108.75 | 43.82 | 1.67 |
| $T_8$, $T_2$ + foliar application of 20 g urea/litre water at 60, 75 and 90 DAS | 2.20 | 8.82 | 61.71 | 93.31 | 31.59 | 1.51 |
| $T_9$, $T_2$ + foliar application of 20 g $KNO_3$/litre water at 60, 75 and 90 DAS | 2.54 | 9.06 | 64.76 | 107.44 | 42.69 | 1.66 |
| $T_{10}$, no nitrogen (Control) | 1.02 | 5.85 | 41.94 | 44.30 | 2.36 | 1.05 |
| SEm± | 0.08 | 0.44 | - | 3.19 | 2.80 | - |
| CD (P=0.05) | 0.23 | 1.31 | - | 9.49 | 8.32 | - |

Market rates: Seed cotton ₹ 40,500/t and cotton stalk ₹ 500/t
Details of treatments are given under materials and methods

**Table 3.** Nutrient uptake (kg/ha) and Agronomic and physiological N-use efficiency of Bt. cotton as influenced by split and foliar application of nitrogen (mean data of 2 years)

| Treatment | N uptake (kg/ha) | P uptake (kg/ha) | K uptake (kg/ha) | Agronomic N-use efficiency (kg yield increase/kg N applied) | Physiological N-use efficiency (kg yield increase/kg N uptake) |
|---|---|---|---|---|---|
| $T_1$, N application in 3 equal splits at sowing, 30 and 60 Days after sowing (DAS) | 152.3 | 34.9 | 90.0 | 9.8 | 16.9 |
| $T_2$, N application in 3 splits as 20, 40, 40% at sowing, 30 and 60 DAS | 146.2 | 33.1 | 87.5 | 8.3 | 16.3 |
| $T_3$, N application in 4 equal splits at sowing, 30, 45 and 60 DAS | 175.1 | 36.8 | 97.0 | 12.5 | 16.4 |
| $T_4$, N application in 5 equal splits at sowing, 30, 45, 60 and 75 DAS | 191.1 | 42.8 | 115.5 | 13.9 | 15.6 |
| $T_5$, N application in 6 splits as 20% at sowing and remaining in 5 equal splits at 30, 45, 60, 75 and 90 DAS | 221.6 | 46.4 | 129.1 | 15.9 | 14.3 |
| $T_6$, $T_1$+ foliar application of 20 g urea/litre water at 60, 75 and 90 DAS | 168.3 | 38.1 | 95.4 | 12.1 | 17.2 |
| $T_7$, $T_1$ + foliar application of 20 g $KNO_3$/litre water at 60, 75 and 90 DAS | 178.4 | 40.9 | 127.0 | 12.4 | 16.0 |
| $T_8$, $T_2$ + foliar application of 20 g urea/litre water at 60, 75 and 90 DAS | 151.0 | 36.0 | 96.6 | 9.4 | 16.7 |
| $T_9$, $T_2$ + foliar application of 20 g $KNO_3$/litre water at 60, 75 and 90 DAS | 173.5 | 37.9 | 121.3 | 12.2 | 16.1 |
| $T_{10}$, no nitrogen (Control) | 79.5 | 16.8 | 48.0 | - | - |
| SEm± | 7.1 | 3.0 | 4.2 | 0.6 | 1.5 |
| CD (P=0.05) | 21.2 | 9.0 | 12.5 | 1.9 | NS |

Details of treatments are given under materials and methods

and ammonia volatilization were checked by split application. This was possibly due to the fact that under more number of split, plants used N efficiently and rapidly for their growth with minimum wastage. Thus, agronomic nitrogen-use efficiency increased.

The effect of split and foliar application of nitrogen on physiological N-use efficiency was found non-significant (Table 3). However, N application in 3 equal splits at sowing, 30 and 60 DAS + foliar application of 20 g urea/litre water at 60, 75 and 90 DAS recorded the highest physiological N-use efficiency, whereas N application in 6 splits (20% at sowing and remaining in 5 equal splits at 30, 45, 60, 75 and 90 DAS) recorded the lowest physiological N-use efficiency. Less uptake of nitrogen might have resulted in higher physiological nitrogen-use efficiency in the treatments N application in 3 equal splits at sowing, 30 and 60 DAS + foliar application of 20 g urea/litre water at 60, 75 and 90 DAS.

It can be concluded that under irrigated condition of western Maharashtra for achieving the higher seed-cotton yield and net returns from the Bt. cotton, the recommended dose of nitrogen (125 kg N/ ha) should be applied in 6 splits as 20% at sowing and remaining in 5 equal splits at 30, 45, 60, 75 and 90 DAS on Inceptisol soil.

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