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RESPONSE OF NITROGEN FERTILIZATION ON BT AND NON-BT COTTON (*Gossypium hirsutum*) HYBRIDS

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ABSTRACT

A field experiment was conducted during 2006 and 2007 (June-December) at New Delhi to assess the performance of three cotton hybrids of which two Bt (MRC 6304 & RCH 317) and one non-Bt cotton hybrid LHH 144 (North zone check) in response to nitrogen fertilization (0, 60, 120 and 180 kg ha^{-1}). Based on pooled analysis, both Bt hybrids produced similar seed cotton yield (SCY). Bt hybrid have produced 7.1 bolls/plant (on an average) and bolls 0.48 g heavier than non Bt hybrid LHH 144 that lead to 1.07 t ha^{-1} higher SCY of Bt hybrids than non-Bt hybrid (1.93 t ha^{-1}). Though the N uptake by cotton hybrids was statistically similar N harvest index (NHI) was higher in Bt hybrid (57.85) as compared to non-Bt hybrid (40.5). The agronomic N use efficiency (ANUE) was highest in MRC 6304 Bt (6.44) and least in LHH 144 non-Bt cotton (3.91). Cotton growth, yield attributes, SCY, and N uptake increased with each successive increase to the highest level of 180 kg ha^{-1}however, the N response of cotton was quadratic in nature with optimum dose of 173.0 kg ha^{-1}. The NHI decreased with increase in N dose i.e. from the highest of 56.3 in control to the lowest of 48.8 with 180 kg ha^{-1} N fertilization. ANUE and physiological NUE that was highest with 60 (5.73) and120 kg N fertilization (17.05), respectively and decreased with further increase in N dose. The cotton hybrid x N interaction effect revealed that Bt cottons have quadratic N response while non-Bt cotton has linear N response. From the economic point of view, Bt hybrids with 120 kg Nha^{-1} could be optimum dose for cotton cultivation.

Key words: Bt cotton, nitrogen, nitrogen use efficiency, N harvest index (NHI), seed cotton yield (SCY), economics

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INTRODUCTION

Cotton (*Gossypium* sp) is the most important commercial fibre crop of India since time immemorial. Its productivity however, has made little progress since independence. The severe incidence of bollworm complex owes major responsibility for the low cotton productivity in the country. The initial success with 4th generation synthetic pyrethroids in the early 1980's for control of bollworms in cotton was lost with gradual resistance development to these pesticides. The costly and partially successful pest management practices made cotton farming uneconomical. The development of cotton hybrids with a gene from the soil bacterium *Bacillus thuringiensis* (Bt) by Monsanto enabled the plant to produce toxins to defend against bollworms attack. The Bt cotton hybrids were commercialized in USA in 1996 and subsequently introduced to Central and Southern cotton zones of India in 2002 with the grant of permission for cultivation of three Bt cotton hybrids. Subsequently in 2005, six Bt cotton hybrids were approved for cultivation in North cotton zone. Recent region-specific studies in India have found that Bt hybrids improved yields by 45-87 per cent (AICCIP, 2007). The economic gains reported in India with Bt cottons has been primarily due to reduced costs of pest control, and increased yields (Qaim et al., 2009). The lowered seed costs between Bt and Non-Bt hybrids (Bt prices to Rs. 750/packet since 2006 as compared to non-Bt hybrids price of Rs 450/packet) have further made Bt technology acceptable to farmers (Kameswara Rao, 2006).

Nitrogen, an integral component of many plant compounds such as amino acids, that are the building blocks of proteins, is a vital nutrient for the growth and development of cotton. As N is a mobile element, its deficiency during the early and mid season results in the chlorosis of older leaves. Its deficiency also leads to reduced plant height, fruiting branches and increased boll shed (Hodges, 1995). The yield response of Bt cotton (Pettigrew and Adamczyk, Jr., 2006) and increases in Bt protein content with N fertilization (Yang Chang Qin et al., 2005) demands adequate N fertilization. The information on comparative performance of Bt and non-Bt cottons under different nitrogen fertilization levels in Northern Indo-Gangetic Plains of India is lacking. Hence the present study was undertaken to find the response of Bt cotton to different N fertilizer for highest yield and economic return.

MATERIALS AND METHODS

Field experiments were conducted during June-December of 2006 and 2007 at the research farm of Indian Agricultural Research Institute, New Delhi. The experimental soil was sandy loam with 7.8 and 7.7 pH containing 3,700 and 3,800 kg ha^{-1} organic carbon, 166 and 168 kg ha^{-1} of $KMnO_4$ extractable N, 14.7 and 14.5 kg ha^{-1} 0.5 M $NaHCO_3$ extractable P and 179 and 173 kg ha^{-1} NH_4OAC extractable K at the start of experimentation in 2006 and 2007. The trial was laid out in split plot design with 3 cotton hybrids viz., MRC 6304, RCH 134 (Bt cottons), and LHH 144 (non-Bt hybrid with resistance to leaf curl virus used as check in the North zone) as

main plots and 4 nitrogen (N) levels (0, 60, 120, and 180 kg ha^{-1}) as sub-plot. A sub-plot of 5.4 m x 4.8 m size was used. The treatments were replicated thrice. Single cotton seed was dibbled at 120 cm x 60 cm spacing on a well prepared soil in first week of June followed by irrigation. Some seedlings were gap filled at 15 days after sowing (DAS) with seedlings grown simultaneously in plastic bags for this purpose. The seed cotton was collected in three pickings starting from October and after final picking (the crop stalks were harvested) in first week of December 2006 and in the last week of November 2007 (Plot size given). The crop received 26.4 kg ha^{-1} of phosphorus (P) and 36 kg ha^{-1} potassium (K) as single super phosphate and muriate of potash,and nitrogen (N) was given as per the treatments through prilled urea. Entire P and K fertilizers were broadcast applied to soil uniformly and were mixed with the soil by tractor drawn cultivator before sowing. Nitrogen was applied after irrigation in 3 equal splits 15, 40 and 80 DAS coinciding with gap filling, square and early boll formation stages, respectively. In non-Bt cotton, one spray of monocrotophos 36% SL @ 2 liters (85 DAS) and two sprays of Spinosad 45% SC (Tracer) @ 100 ml (110 and 135 DAS) dissolved in 500 liters of water was applied/ha to protect crop against boll worm complex. During the experimental years from June- December / November 499.3 and 457 mm of rainfall was received in 2006 and 2007, respectively. The crop received irrigations as per need. However, during 2007, the crop faced a slight moisture stress for 15 days in mid to end of July (at square formation). Plant height was recorded at last picking stage. The leaf area expressed as leaf area index (LAI) and dry matter production (DMP) was recorded at 30 days interval from sowing to harvest for two plants. A single plant from second row from border was cut to the ground level in the morning hours (9.00 AM) and were shifted immediately to laboratory and leaves were separated immediately and the leaf area was recorded with the help of leaf area meter (model LI-3100 USA). LAI was calculated as ratio of leaf area (cm^2) /plant to that of land area occupied by plant (7200cm^2). The defoliated plant and leaf samples after recording leaf area were kept in paper bags and was oven dried at 60^0C for 48 hours and their total weight (g) was recorded. The dry matter values were reported as g/m^2 by multiplying dry weight of plant with number of plants/m^2i.e. 1.388. The LAI values reached their highest values at 120 DAS and the LAI and DMP values were reported for this stage only The nitrogen concentration of economic produce and cotton sticks along with leaves retained on plant at harvest was determined by kjeldahl.s method (Jackson, 1973) and uptake was obtained as product of concentration and yield. N harvest index was worked out as ratio of uptake in seed cotton to total uptake. Partial factor productivity was worked out as ratio of economic yield and amount of N application. Agronomic efficiency of N was calculated as ratio of yield (yield in N applied-yield in no N applied plot in kg ha^{-1}) and amount (kg ha^{-1}) of N applied. Physiological efficiency of N was worked out as ratio of yield (yield in N applied plot-yield in no N applied plot) and N uptake (uptake in N applied- uptake in no N plot). In calculation of economics, minimum support price was taken for seed cotton (Rs. 20,100/t of seed

cotton) and dry weight cotton stalks of Rs. 1,000/ton. The N fertilizer price of Rs.11/ kg was used. Seed cotton picking cost was taken as Rs. 500/t, while stalk harvesting was taken @ 100/t. Seed cost was taken as Rs. 1,125/ ha for non- Bt cotton, LHH 144 and Rs. 1, 875/ha for Bt hybrids.

RESULTS AND DISCUSSION

Growth and yield attributes

The results indicate significant influence of cotton hybrids and N levels on the growth and yield attributes of cotton (Table 1). The two Bt hybrids were on average 12.4 cm shorter than non-Bt hybrid (126.6 cm). Non-Bt cotton recorded significantly higher LAI values than the two Bt cotton hybrids. LAI of non-Bt cotton hybrid on an average has 0.57 higher than two Bt hybrid. The two Bt hybrids have statistically similar LAI values. Nitrogen fertilization enhanced the plant height and LAI markedly up to the highest level (180 kg ha^{-1}) of its application. However, the increase in plant height in both the years and LAI during second year beyond 120 kg N application was not marked. The plant height and LAI (mean of two years) increased by 11.1 cm and 0.73 with 60 kg N fertilization over control. The respective increase in plant height and LAI was 5.8 cm and 0.17 and 4.4 cm and 0.14 with application of 120 and 180 kg N fertilizer over 60 and 120 kg N/ha, respectively. Similar differences in growth attributes among Bt and non-Bt cotton hybrids (Singh et al., 2007a) and N fertilization (Fernandez et al., 1996) were also reported. The highest dry matter was produced from non Bt hybrid in both the years at 120 DAS and was significantly higher than Bt hybrids (Table 1).

Growth attributes were higher in non Bt hybrid but yield attributes showed reverse behaviour. The yield attributes (boll number and boll weight) of Bt hybrids were similar. The Bt hybrids on an average had 7.13 extra bolls /plant compared to non-Bt hybrid (LHH-144). Similarly Bt hybrids produced bolls weighing 0.48 g more than that of the non-Bt cotton hybrid LHH 144. Each successive increase of N dose from unfertilized control to the highest level of 180 kg/ha increased the boll number and boll weight but at par to 120 kg N ha^{-1}. Application of 180 kg N ha^{-1} produced mean boll number of 54/plant and boll weight of 4.35 g which was 40 and 8.3% greater over no nitrogen fertilizer applications (38.55 and 4.015 g). The lower boll number and boll weight of cotton in unfertilized control plots was due to inadequate N supply from the soil that was rated low in available N. The reduced leaf area (source) failed to satisfy the assimilate needs of growing bolls (sink), leading to their shedding resulting in less number of bolls per plant. Further, the retained bolls were of lighter in weight. A decrease in leaf area (Fernandez et al., 1996) and associated lower assimilates supply leading to low yield attributes formation was also reported by Raja Reddy et al. (2003). The interaction effect of cotton hybrids and nitrogen fertilization on yield attributes was found non-significant.

Seed cotton yield

The seed cotton yield (SCY) was significantly influenced by cotton hybrids, N levels (Table 1), and their interaction (Table 2). The SCY l was less in the second year by 0.3 ton than that in first year (2.79 t ha^{-1}). This was ascribed to the moisture stress in the later year due to failure of water supply coinciding with square formation starting from mid July for a fortnight.

The two Bt hybrids being at par produced 1.07 t ha^{-1} higher SCY (64.7%) than non-Bt hybrid LHH 144. (Table 1) The better performance of Bt cottons were ascribed to higher boll numbers/plant and heavier boll weight. Similar differences among Bt and non-Bt cotton hybrids were also reported from India by Nehra et al. (2004) Singh et al. (2007b) Singh et al. (2007a) and Yudhveer Singh et al. (2010).

Each successive increase of N dose increased the seed cotton yield up to 180 kg N/ha during the first year. However, in the second year, response to N beyond 120 kg was not marked. The SCY increased by 0.35, 0.32 and 0.12 t ha^{-1} with application of 60, 120, 180 kg N over control, 60 and 120 kg N, respectively. The increase in SCY with N application was ascribed to the effect of N on boll number and boll weight

The interaction effect of cotton hybrids and N fertilization on pooled SCY (Table 2) indicate that SCY of Bt cotton hybrids increased up to 120 kg N $ha^{-1,}$ whereas in non-Bt cotton SCY increased upto the highest levels of N (180 kg ha^{-1}). The differential response of Bt and non-Bt hybrids to N could be ascribed to the short and determinate nature of the former as compared to long and indeterminate growth habit of the later.

Stalk yield

The cotton stalk yield (CSY) i.e. the dried cotton stalk along with the leaves retained on plant at harvest and bolls (after removing seed cotton) was significantly influenced by cotton hybrids and N levels (Table 1). The non-Bt hybrid (LHH 144) on an average produced 11.5% (0.63 t/ha) higher stalks than Bt hybrids. The cotton stalk yields of both Bt hybrids were statistically similar and the differences in stalk yield between Bt and non-Bt hybrids could be ascribed to taller plants and more branching (visual observation) of the former. Each successive increase of N dose increased the cotton stalk yield up to 180 kg N ha^{-1} during both the years but statistically at par to 60 kg N ha^{-1}. The cotton stalk yield on an average increased by 0.68, 0.35 and 0.21 t ha^{-1} with 60, 120, 180 kg N fertilization over control, 60 and 120 kg N respectively. The increase in cotton stalk yield with N fertilization was ascribed to its impact on plant height and also on branching.

N uptake and use efficiency parameters

The N uptake of cotton hybrids (both Bt and non Bt) were statistically similar, but LHH 144 has 8.83 kg ha^{-1} less uptake than Bt hybrids. However, the amount of N present in seed cotton was highest (57.85%) in Bt cotton while non-Bt has lowest

(40.5%) amount (Table 3). The low values of non Bt cotton was ascribed to the fact that it has indeterminate growth habit and thus has more N in vegetative parts at end of November. The total N uptake increased with each successive increase from 0 to 180 kg ha^{-1}. The increased N uptakes with N fertilization as compared to unfertilized (control) cotton crop of the present study are in close agreement with the findings of Raman Jeet Singh et al. 2009). The share of seed cotton N in total uptake (NHI) decreased with increase in N dose. It was 56.3, 52.4, 51.5 and 48.8 % in control, 60,120 and 180 kg ha^{-1} N fertilization, respectively. The increase in total uptake with increasing N dose was ascribed to the increased N concentration and yield (seed cotton and stalk, leaves etc) of crop. In the present study, the N uptake of stalk and leaves retained on plant at harvest was only considered, indicating lower estimation of N uptake owing to non-consideration of uptake of senesced leaves up to maturity. The decrease in seed cotton share in total N uptake with increasing N dose indicates that a greater portion of it is retained in stems and green leaves at higher N dose.

The partial factor productivity of nitrogen, PFP (kg seed cotton/kg N applied), agronomic N use efficiency, ANUE (kg seed cotton/kg N applied), and physiological N use efficiency, PNUE (kg seed cotton/kg N uptake) of Bt hybrids (31.29, 6.00 and 16.75) were higher than non-Bt LHH 144 (20.13, 3.91 and 14.12). The higher ANUE of Bt hybrids as compared to non-Bt hybrid was ascribed to greater increase in SCY with N fertilization in the former as compared to the later. Among N fertilization, the PFP, ANUE and PNUE were highest with 60, 60 and 120 kg N fertilization (42.33, 5.73 and 17.05) respectively and it decreased thereafter and their lowest values (16.56, 4.30 and 15.22) were recorded with the highest application rate (180 kg ha^{-1}). The decreasing PFP, ANUE and PNUE with increase in N dose were ascribed to the fact that the increase in seed cotton yield was not in proportionate to the N application rate and N uptake respectively.

Response functions

The response of seed cotton yield to N application as influenced by cotton hybrids and N levels was worked out from seed yield data by fitting response equation based on mean data of two years (Table 4). The equations revealed that response of seed cotton yield to N was quadratic with high R^2 values. The optimum dose of N for cotton was170.3 kg ha^{-1} , the response per kg N at optimum dose in terms of seed cotton yield was worked out to be 3.96 and the returns on each rupee of investment on N was Rs 6.23. Based on N response, MRC 6304 was found more efficient in utilizing N and producing economic yields. Non-Bt cotton response to N was found linear.

Economics

The economic analysis of the investigation (Table 5) revealed that Bt cotton hybrids enhanced more cost of cultivation by Rs. 1190/ ha over non-Bt cotton. Of this, Rs. 750 and 535, were due to seed and seed cotton picking costs, while stalk harvesting costs were reduced by Rs 86 /ha. The Bt hybrids showed 88% (Rs.

19,357/ha) higher net returns than non-Bt hybrid cotton. The higher seed cotton productivity of Bt hybrids (1.07 t ha^{-1}) with marginal increase (Rs. 1190/ ha) in cost of cultivation (Rs. 750 due to seed and rest due to increased seed cotton picking costs) as compared to non-Bt hybrids has resulted in the above trend of net returns. The N fertilization of Bt cotton has enhanced net returns with each successive increase of 60 kg N dose to the highest levels of 180 kg N ha^{-1}. Benefit cost ratio (BCR) showed similar in two Bt hybrids and much higher than non Bt hybrids. There was trend to increase BCR up to 120 kg N ha^{-1} (2:67) and decreased with the increase of N level 180 kg ha^{-1} (2:53).

From the study it is concluded that Bt cotton hybrids are superior to non-Bt hybrid (LHH 144) both in seed cotton yield and net returns point of view. Economic analysis showed that 120 N kg ha^{-1} gave higher benefit, so this dose is recommended for cotton cultivation.

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Table 1: Growth, yield attributes and yields of Bt and non-Bt cotton hybrids as influenced by nitrogen fertilization

Treatment	Total N uptake (kg ha^{-1})	N retained (kg ha^{-1})in seed cotton	N Harvest Index	ANUE (kg seed cotton /kg N applied)	Physiological NUE (kg seed cotton/kg uptake)	Partial factor productivity of N (kg seed cotton/kg N applied)
Cotton hybrid						
MRC 6304 (Bt)	118.0	68.3	57.9	6.44	16.97	31.42
RCH 134 (Bt)	117.7	68.0	57.8	5.56	16.53	31.15
LHH 144 (non-Bt)	109.0	44.1	40.5	3.91	14.12	20.13
SEm±	3.1	2.4	-	-	-	-
CD (P=0.05)	9.6	7.5	-	-	-	-
Nitrogen dose (kg ha^{-1})						
0	87.6	49.3	56.3	-	-	-
60	110.4	57.9	52.5	5.73	15.35	42.33
120	126.9	65.4	51.5	5.55	17.05	23.83
180	139.5	68.1	48.8	4.30	15.22	16.56
SEm±	2.0	1.6	-	-	-	-
CD (P=0.05)	5.7	4.6	-	-	-	-

Table 2: Interaction effect of cotton hybrids and nitrogen fertilization on pooled seed cotton yield (t ha^{-1}).

Nitrogen dose (kg ha^{-1})	Cotton hybrid		
	MRC 6304 Bt	**RCH 134 Bt**	**LHH 144**
0	2.45	2.52	1.59
60	2.90	2.88	1.85
120	3.27	3.22	2.06
180	3.36	3.35	2.23
SEm±	0.06		
CD (P=0.05)	0.17		

Table 3: N uptake and use efficiency parameters of different varieties as influenced by levels of nitrogen fertilization of cotton (Pooled).

Treatment	Plant height (cm) 2006 2007	LAI at 120 DAS 2006 2007	Dry matter production (g/m^2) at 120 DAS 2006 2007	Bolls/Plant 2006 2007	Boll weight (g) 2006 2007	Seed cotton (*kapas*) yield (t ha^{-1}) 2006 2007	Cotton stalks yield (t ha^{-1}) 2006 2007
Cotton hybrid							
MRC 6304 (Bt)	125.2 101.7	3.38 3.28	311.5 307.3	51.4 45.6	4.38 4.35	3.12 2.87	5.60 4.95
RCH 134 (Bt)	125.7 104.3	3.31 3.19	310.2 308.0	51.2 47.5	4.35 4.34	3.05 2.93	5.47 5.05
LHH 144 (non-Bt)	134.8 118.3	3.90 3.82	415.5 408.6	43.8 39.8	3.90 3.85	2.21 1.65	6.35 5.90
SEm±	3.1 2.7	0.07 0.06	9.0 8.4	1.2 0.97	0.09 0.07	0.058 0.027	0.10 0.09
CD (P=0.05)	9.7 8.5	0.22 0.19	28.2 26.3	3.7 3.03	0.28 0.21	0.18 0.08	0.31 0.28
Nitrogen dose (kg ha^{-1})							
0	120.5 91.6	2.85 2.90	313.5 320.8	37.3 39.8	4.05 3.98	2.34 2.03	5.10 4.50
60	126.5 107.8	3.45 3.32	349.5 339.7	46.7 42.8	4.18 4.20	2.66 2.42	5.75 5.20
120	131.8 114.1	3.85 3.69	357.3 349.8	51.3 46.6	4.24 4.22	3.01 2.70	6.10 5.65
180	135.8 118.9	3.93 3.81	362.9 355.7	59.9 48.0	4.37 4.32	3.17 2.79	6.25 5.83
SEm±	2.1 1.9	0.05 0.04	4.9 4.6	0.81 0.66	0.06 0.05	0.04 0.03	0.07 0.06
CD (P=0.05)	6.0 5.3	0.14 0.11	14.0 13.1	2.3 1.89	0.17 0.13	0.11 0.09	0.19 0.17

Table 4: N response functions based on mean data of two years

Treatment	Equation (R^2)	Optimum N dose (kg ha^{-1})	N response (kg seed cotton/kg N)	Returns (Rs/Re invested on N)
MRC 6304	$y = 2.4376 + 0.00968x - 0.0003x^2$ (R^2=0.9948)	152.21	5.11	8.34
RCH 134	$y = 2.5021 + 0.00773x - 0.00002x^2$ (R^2=0.9953)	179.57	4.14	6.57
Mean N response	$y = 2.1772 + 0.00736x - 0.00002x^2$ (R^2=0.9975)	170.30	3.96	6.23

y: yield in tons ha^{-1}; x; dose of N in kg ha^{-1}

Table 5: Economics of Bt and non-Bt cotton cultivation as influenced by nitrogen fertilization

Treatment	Cost of cultivation (Rs ha^{-1})	Gross Returns (Rs ha^{-1})	Net Returns (Rs ha^{-1})	Benefit cost ratio (BCR)
Cotton hybrid				
MRC 6304 (Bt)	24,100	65,580	41,480	2.72
RCH 134 (Bt)	24,100	65,359	41,259	2.71
LHH 144 (non-Bt)	22,910	44,923	22,013	1.96
Nitrogen dose (kg ha^{-1})				
0	22,000	48,819	26,819	2.22
60	23,013	56,936	33,923	2.47
120	23,723	63,366	39,643	2.67
180	26,079	65,938	39,859	2.53