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Review/Overview

Nutrient requirement of Bt. cotton (*Gossypium hirsutum*)

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ABSTRACT

A field experiment was conducted on *Vertisols* of Dharwad, Karnataka during the rainy seasons of 2007 and 2008, to ascertain the nutrient requirement of Bt cotton (*Gossypium hirsutum* L.**)** with the recommended dose of fertilizer (RDF, 120–60–60 kg N P_2O_5 K_2O/ha) advocated to the conventional non-Bt cotton hybrid. The investigation focused on varying the recommended nitrogen application levels into 7 splits–10% as basal, remaining 90% in equal splits at 30, 60, 75, 90, 105 and 120 days after sowing (DAS)–with entire dose of P and K coupled with the soil application of $MgSO_4$ @ 25 kg/ha, foliar nutrition of urea (2%), DAP (2%), $MgSO_4$ (1%), KNO_3 (2%), calcium nitrate (1%), multimicronutrient (1%), Cytokinin (2 ppm) and polyethylene mulching (100 micron thickness). 'Bunny Bt (NCS 145)' cotton genotype was sown with 90 cm × 60 cm spacing. Foliar application of KNO_3 2%, soil and foliar application of $MgSO_4$ @ 25 kg/ha and 1% respectively, and soil application of $MgSO_4$ @ 25 kg/ha alone increased the seed-cotton yield by 25.0, 24.4 and 24.3% respectively, over the RDF. Sympodial branches and total number of bolls/plant followed the similar trend. At 120 DAS, increase in leaf potash content (1.02%) was recorded with foliar application of 2% KNO_3 and the increase in leaf magnesium (1.86%) was noticed with soil and foliar application of $MgSO_4$ @ 25 kg/ha and 1% respectively. Significantly increased 2.5% span length (33.1 mm) and bundle strength (24.8 g/tex) were observed with foliar application of KNO_3 (2%) over the other treatments. Foliar application of KNO_3 (2%) (3 sprays on 15 October, 1 November and 31 November) significantly increased the seed-cotton yield (2.54 t/ha), gross returns (₹56.2 × 10^3/ha), net returns (₹27.8 × 10^3/ha) and benefit: cost ratio (1.98).

Key words : Bt-cotton, Crop management, Economics, Fibre quality, Foliar nutrition, Growth regulator, Leaf nutrient content, Polyethylene mulching

Area-wise, India ranks first in global scenario (about 33% of the world cotton area). However, in production it ranks second next to China. In India, Bt cotton since its release in 2002 by Genetic Engineering Approval Committee (GEAC) replaced more and more conventional cotton area. There was an exponential increase in Bt cotton area from 29,000 ha in 2002 to 11.77 mha in 2012, accounting for a staggering 92% of the total cotton area in India (AICCIP, 2013). The most important reason for the adoption of Bt cotton is its resistance to pest, particularly bollworms which has been a devastating production constraint (Gandhi and Namboodiri, 2006). Synchronized boll development and better retention of bolls owing to better bollworm control in Bt plants altered the source–sink relationship because of rapid translocation of saccharides and nutrients from leaves to the developing bolls. Scientists (Hebbar *et al.,* 2007) opined that these adversities would develop some physiological disorders. Poor performance of the transgenic traits during boll-development period and varied performance between different regions has been reported (Dong *et al.,* 2005). Another important factor in Bt cotton cultivation is sustained cry protein synthesis, which is responsible for control of boll-worm wherein nitrogen is very much involved (Blaise and Kranthi, 2011). In order to balance the source–sink relationship by way of sustained photosynthetic efficiency and cry protein synthesis at grand growth period of Bt cotton, the leaf nitrogen content (3.5–4.5%) has to be maintained (Brar *et al.,* 2008). Reports indicated the beneficial effects of application of cytokinin on soybean seed yield (Cho, 2002) and the use of polyethylene mulch on seed cotton yield (Halemani *et al*. 2009). In this regard, an attempt was made in the present study with respect to split application

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of recommended dose of nitrogen (10% basal, remaining 90% into equal six splits) in comparison with the recommended 4 splits of N application (50% as basal remaining 50% in equal 3 splits). Besides, additional treatments were superimposed, viz. foliar nutrition (with urea 2%, DAP 2%, $MgSO_4$ 1%, KNO_3 2%, calcium nitrate 1%, multimicronutrient 1%, cytokinin 2 ppm) and polyethylene mulching (100 micron thickness), application of growth hormone (cytokinin 2 ppm) and polyethylene mulching (100 micron thickness) were superimposed from the second fortnight of October (wherein the cotton-growth stage normally coincides with the onset of low temperature in the season) onwards to ensure adequate nutrient supply to keep the pace of source–sink relationship in Bt cotton. This investigation focused on adequate supply of nutrients for normal growth and development of Bt cotton for getting sustained seed-cotton yield.

MATERIALS AND METHODS

A field experiment was laid out in a randomized complete-block design with 3 replications on *Vertisols* at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, during the rainy (*kharif*) seasons of 2007 and 2008 having 0.55% organic carbon. The initial soil nutrient content were available nitrogen (210.7 kg/ha), phosphorus (17.6 kg/ha), potassium (440.2 kg/ha), calcium (32.5 kg/ha) and magnesium (17.5 kg/ha). The total rainfall received during the cropping period (First week of June to last week of January) during the first season (2007–08) was 922 mm with 51 rainy days and during the second season (2008–09), it was 730.8 mm with 46 rainy days and the crop experienced well-distributed rainfall. 'Bunny Bt' 'NCS 145' genotype sowing was sow on 25 July 2007 and on 27 July 2008 at 90 cm × 60 cm spacing. The fertilizer was applied as per the treatment specifications. The recommended fertilizer dose to the conventional non-Bt cotton hybrid under transitional tract of Dharwad is 120–60–60 kg N P_2O_5 K_2O/ha, the application is being advocated with entire dose of P, K and 50% N as basal and the remaining 50% N in 3 splits–50, 80 and 110 DAS. An attempt was made to ascertain the nutrient requirement with the same recommended fertilizer dose (to the conventional non-Bt cotton hybrid) with the additional nutrients in Bt cotton cultivation to get sustained seed-cotton yield. The investigation focused on varying the nitrogen application levels into 7 splits (10% as basal, remaining 90% in equal splits at 30, 60, 75, 90, 105 and 120 DAS) (as per detail in table 1, T_1 to T_{12}) (Table 1) treatments along with the superimposed treatments, comprising foliar nutrition, growth hormone (Cytokinin) and polyethylene mulching with entire dose of P and K as basal. Foliar spray of urea (2%), DAP (2%), $MgSO_4$ (1%), KNO_3 (2%), calcium nitrate (1%), multimicronutrient (1%) and cytokinin (2 ppm) were superimposed respectively, to the treatments T_2, T_3, T_4, T_5, T_6, T_7 and T_8 on the 15 October, 1 November and 15 November. Multimicronutrient (1%) mixture comprised zinc, manganese, iron, copper, molybdenum and boron. Treatment T_9 was superimposed with $MgSO_4$ @ 25 kg/ha with foliar application of $MgSO_4$ @ 1% on the 15 October, 1 November and 15 November. The treatment, T_{12} was superimposed with transparent polyethylene mulching (100 micron thickness) on the 15 October and was retained in the field till the harvest of the crop. To the check treatment T_{11}, the recommended dose of fertilizer (120–60–60, N-P-K kg/ha) was applied (entire dose of P, K and 50% N as basal and the remaining 50% N into 3 equal splits at 50, 80 and 110 DAS) and foliar application of $MgSO_4$ @ 1% at 90 DAS. The plant-protection measures for sucking pests (leaf hoppers, thrips, aphids and white flies) were adopted commonly in all the treatments. Two hand-weedings at 25 and 45 DAS and 2 intercultivations at 45 and 65 DAS were carried out to keep the plots free from weeds and to close the cracks developed during the crop growth period to reduce evaporation losses in both the years. At 120 DAS, fully expanded third leaf was selected from the top for analysis of nutrient content by adopting standard procedures. The data were statistically analysed. The economics of cost of cultivation, net returns and return/rupee investment (benefit: cost ratio) were worked out taking into account the cost of various inputs as well as the price of seed-cotton yield prevailed during 2007–08 and 2008–09.

RESULTS AND DISCUSSION

The crop experienced well-distributed rainfall during its grand growth period during both the seasons (2007 and 2008). The results are summarized here with the pooled data.

Growth parameters and yield attributes

Total number of bolls is the result component of number of good opened bolls and number of bad opened bolls/plant. Significantly higher number of good opened bolls/plant, lower number of bad opened bolls/plant and increased total number of bolls/plant were noticed with the soil application of $MgSO_4$ (25 kg/ha) and foliar application of $MgSO_4$ (1%) and it was on a par with the foliar application of KNO_3 (2%) and soil application of $MgSO_4$ @ 25 kg/ha (Table 1). Sympodial branches/plant also followed the similar trend (Table 1) whereas the number of monopodial branches were not influenced by the treatments. Foliar application of KNO_3 (2%) increased the number of good opened bolls, boll weight (Kaur *et al.*,

2007; Sharma and Singh, 2007) and sympodial branches/plant (Brar *et al.,* 2008).

In cotton, yield is directly related to boll number, boll weight and seed-cotton yield/plant. The higher seed-cotton yield with the foliar application of KNO_3 (2%) is supported by significantly increased boll weight and seed-cotton yield/plant (Table 1). Foliar application of KNO_3 (2%) -increased 18% boll weight (g/boll) and 19% seed-cotton yield (g/plant) than the recommended package. Similar trend was observed with the soil application of $MgSO_4$ (25 kg/ha) and also with the soil application of $MgSO_4$ (25 kg/ha) and foliar application of $MgSO_4$ (1%). Blaise *et al.* (2009) reported the increased boll weight due to foliar application of KCl.

Seed-cotton yield

Foliar application of KNO_3 (2%) gave significantly higher seed-cotton yield over others and was on a par with the soil application of $MgSO_4$ @ 25 kg/ha and foliar application of $MgSO_4$ (1%) and soil application of $MgSO_4$ @ 25 kg/ha alone (Table 1). The lowest seed-cotton yield was recorded with the polyethylene mulching treatment. The seed-cotton yield increased with the foliar application of KNO_3 (2%) by 25.1%, soil application of $MgSO_4$ @ 25 kg/ha and foliar application of $MgSO_4$ (1%) by 24.4% and soil application of $MgSO_4$ @ 25 kg/ha alone by 24.3% over the recommended dose of fertilizer (RDF). At 120 DAS, the leaf potash content (1.02%) increased with the foliar application of KNO_3 (2%). It can be inferred from the results obtained that application of KNO_3 (2%) is a good source of nitrogen and potash nutrition for maintaining the threshold level for Bt cotton growth and development. Brar *et al.*(2008) similar observation. Reports indicated that modern cotton transgenic varieties with fast fruiting, high yielding or heavy boll load and early maturity, seem to be more susceptible to K limitation than traditional varieties (Wright, 1999).

Soil and foliar application of $MgSO_4$ also increased the seed-cotton yield because of magnesium which is an integral part of chlorophyll. Magnesium helps in increased photosynthesis and thereby increased the seed-cotton yield. In the present investigation, at 120 DAS the leaf magnesium content increased significantly with the soil and foliar application of $MgSO_4$ @ 25 kg/ha and 1% re-

Table 1. Seed cotton yield and yield parameters as influenced by different treatments in Bt cotton 'NCS 145' (pooled data of 2 years)

Tr. No.	Treatment	Sympodial branches/ plant	Boll weight (g/boll)	Total number of bolls/plant	Seed cotton yield (g/plant)	Seed cotton yield (t/ha)
T_1	120 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha (10% N, full P and K as basal and 90% N in equal to 6 splits)	16.2	4.06	47.5	80.7	20.8
T_2	T_1+ Foliar application of Urea @ 2% three times at an interval of 15 days from October II FN	15.9	4.07	48.7	82.1	21.1
T_3	T_1+ Foliar application of DAP @ 2% three times at an interval of 15 days from October II FN	16.3	4.19	47.0	82.3	21.1
T_4	T_1+ Foliar application of $MgSO_4$ @ 1% three times at an interval of 15 days from October II FN	16.6	4.13	49.0	82.6	21.1
T_5	T_1+ Foliar application of KNO_3 @ 2% three times at an interval of 15 days from October II FN	17.0	4.85	50.5	98.2	25.4
T_6	T_1+ Foliar application of calcium nitrate @ 1% three times at an interval of 15 days from October II FN	16.1	4.04	47.5	86.8	21.2
T_7	T_1+ Foliar application of multimicronutrient @ 1% three times at an interval of 15 days from October II FN	16.2	4.04	47.9	81.9	21.2
T_8	T_1+ Foliar application of cytokinin @ 2ppm three times at an interval of 15 days from October II FN	16.1	4.01	48.1	78.8	21.1
T_9	T_1+ Soil application of $MgSO_4$ @ 25 kg/ha	17.1	4.81	50.3	101.6	25.2
T_{10}	T_9+ Foliar application of $MgSO_4$ @ 1% three times at an interval of 15 days from October II FN	17.5	4.96	51.9	101.8	25.2
T_{11}	T_1+Mulching of inter row space of 80 cm with polyethylene (100 micron) during the period of October II FN to harvest	14.5	2.91	43.6	50.3	13.8
T_{12}	120 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha (50% N, full P and K as basal and 50% N in equal 3 splits)	15.6	3.96	47.7	78.6	19.1
	SEm±	0.32	0.06	0.98	2.02	9.7
	CD (P=0.05)	0.9	0.2	2.8	5.8	27.2

October II FN, October second fortnight

spectively (1.86%) and with the soil application of $MgSO_4$ @ 25 kg/ha alone (1.82%) compared to other treatments including RDF (1.32%) (Table 2). In the present investigation, despite the leaf magnesium content (1.37%–1.59% at 60 days (0.61%–1.31%) at 90 days and (1.12%–1.86%) 120 days observed well above the sufficiency range (0.25–0.50%). The results confirm the findings of Brar *et al.* (2008). Increased seed cotton yield was observed with foliar application of 2% KNO_3. Brar *et al.* (2008) reported that foliar application of 2% KNO_3 gave additional yield of 300 kg/ha in potash-deficient soils compared to soil application of potassium @ 60 kg/ha. Sharma and Singh (2007) found that application of 2% KNO_3 at initial and peak boll formation increased the seed cotton yield (8.2%), number of opened bolls/plant (34.2%), and boll weight (50%) compared to soil application of N, P and K. Ikisan, (2004) reported the increased seed cotton yield with the soil application of $MgSO_4$ @ 25 kg/ha. Application of cytokinin (2 ppm) found ineffective with respect to growth and yield of Bt cotton.

Fibre quality

Foliar application of KNO_3 (2%) significantly increased the 2.5% span length (33.1 mm) and bundle strength (24.8 g/tex) over the other treatments (Table 3). The fibre fineness did not differ significantly among the treatments. Venugopalan *et al.* (2004) reported that the soil application of potash 30 kg/ha along with foliar spray of potash @ 15 kg/ha significantly increased the 2.5% span length (37.4 mm) over soil application of 45 kg/ha (34.0 mm).

Economics

The economic analysis of different treatments indicated that the total cost of cultivation was maximum for the treatment comprising polyethylene mulching when compared to other treatments (Table 3). Significantly higher net returns were realized with the foliar application of KNO_3 (2%) and it was on par with the soil application of $MgSO_4$ @ 25 kg/ha alone and soil application of $MgSO_4$ @ 25 kg/ha and foliar application of $MgSO_4$ (1%). However, negative net returns were obtained with the polyethylene mulching which indicates economically non-viable production technology which involved major polyethylene sheet cost (₹150.0×10^3/ha). The benefit: cost ratio also followed the similar trend of net returns. Brar *et al.* (2008) reported that foliar application of KNO_3 (2%) yielded higher gross returns, net returns and benefit: cost ratio in

Table 2. Leaf nutrient content (%) in Bt cotton 'NCS 145' as influenced by different treatments (pooled data of 2 years)

Tr. No.	Treatment	Nutrient content (%)				
		N	P	K	Ca	Mg
T_1	120 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha (10% N, full P and K as basal and 90% N in equal to 6 splits)	1.49	0.48	0.61	6.20	1.36
T_2	T_1+ Foliar application of Urea @ 2% three times at an interval of 15 days from October II FN	1.61	0.49	0.64	6.39	1.31
T_3	T_1+ Foliar application of DAP @ 2% three times at an interval of 15 days from October II FN	1.67	0.71	0.65	6.87	1.45
T_4	T_1+ Foliar application of $MgSO_4$ @ 1% three times at an interval of 15 days from October II FN	1.63	0.57	0.67	6.38	1.72
T_5	T_1+ Foliar application of KNO_3 @ 2% three times at an interval of 15 days from October II FN	1.84	0.64	1.02	6.17	1.13
T_6	T_1+ Foliar application of calcium nitrate @ 1% three times at an interval of 15 days from October II FN	1.51	0.61	0.68	7.64	1.23
T_7	T_1+ Foliar application of multimicronutrient @ 1% three times at an interval of 15 days from October II FN	1.49	0.59	0.69	6.27	1.12
T_8	T_1+ Foliar application of cytokinin @ 2 ppm three times at an interval of 15 days from October II FN	1.58	0.56	0.64	6.18	1.35
T_9	T_1+ Soil application of $MgSO_4$ @ 25 kg/ha	1.81	0.59	0.68	6.28	1.82
T_{10}	T_9+ Foliar application of $MgSO_4$ @ 1% three times at an interval of 15 days from October II FN	1.99	0.57	0.67	6.13	1.86
T_{11}	T_1+Mulching of inter row space of 80 cm with polyethylene (100 micron) during the period of October II FN to harvest	1.22	0.55	0.69	6.14	1.31
T_{12}	120 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha (50% N, full P and K as basal and 50% N in equal 3 splits)	1.37	0.41	0.62	5.89	1.32
	SEm±	0.03	0.01	0.01	0.06	0.02
	CD (P=0.05)	0.08	0.03	0.04	0.16	0.12

October II FN, October second fortnight

Table 3. Fibre quality parameters and economic analysis in Bt cotton ' NCS 145' as influenced by different treatments (pooled data of 2 years)

Tr. No.	Treatment	2.5% span length (mm)	Fibre fineness (micronair value)	Bundle strength (g/tex)	Cost of Cultivation (× 10^3 ₹/ha)	Gross return (× 10^3₹/ha)	Net returns (× 10^3₹/ha)	Benefit: cost ratio
T_1	120 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha (10% N, full P and K as basal and 90% N in equal to 6 splits)	31.55	4.32	23.83	27.3	46.1	18.8	1.69
T_2	T_1+ Foliar application of Urea @ 2% three times at an interval of 15 days from October II FN	31.92	4.18	24.13	27.9	46.4	18.5	1.66
T_3	T_1+ Foliar application of DAP @ 2% three times at an interval of 15 days from October II FN	31.53	4.16	23.48	28.2	46.7	18.4	1.66
T_4	T_1+ Foliar application of $MgSO_4$ @ 1% three times at an interval of 15 days from October II FN	31.78	4.25	23.53	28.9	46.6	17.6	1.61
T_5	T_1+ Foliar application of KNO_3 @ 2% three times at an interval of 15 days from October II FN	33.07	4.28	24.80	28.4	56.3	27.8	1.98
T_6	T_1+ Foliar application of calcium nitrate @ 1% three times at an interval of 15 days from October II FN	32.28	4.23	23.92	29.6	46.3	16.6	1.56
T_7	T_1+ Foliar application of multimicronutrient @ 1% three times at an interval of 15 days from October II FN	31.62	4.18	23.87	31.6	46.8	15.2	1.48
T_8	T_1+ Foliar application of cytokinin @ 2ppm three times at an interval of 15 days from October II FN	32.57	4.13	23.73	28.6	46.3	17.6	1.62
T_9	T_1+ Soil application of $MgSO_4$ @ 25 kg/ha	31.90	4.27	23.77	27.9	55.7	27.7	1.99
T_{10}	T_9+ Foliar application of $MgSO_4$ @ 1% three times at an interval of 15 days from October II FN	31.57	4.05	24.23	28.9	55.8	26.9	1.93
T_{11}	T_1+Mulching of inter row space of 80 cm with polyethylene (100 micron) during the period of October II FN to harvest	31.82	4.25	23.45	176.6	30.6	-146.1	0.17
T_{12}	120 kg N, 60 kg P_2O_5 and 60 kg K_2O/ha (50% N, full P and K as basal and 50% N in equal 3 splits)	32.25	4.22	23.80	25.3	42.2	14.4	1.52
	SEm±	0.38	0.10	0.29	-	2.1	2.1	0.07
	CD (P=0.05)	1.08	NS	0.82	-	6.4	6.4	0.20

October II FN, October second fortnight

cotton than soil application of potassic fertilizers. Benefit: cost ratio differed significantly among treatments. Soil application of $MgSO_4$ @ 25 kg/ha recorded significantly higher benefit: cost ratio and was on par with foliar application of KNO_3 (2%) and soil application of $MgSO_4$ @ 25 kg/ha and foliar application of $MgSO_4$ (1%). Lowest benefit: cost ratio was recorded with polyethylene mulching.

Thus application of recommended nitrogen (120 kg/ha) into 7 splits (10% as basal, remaining 90% in equal splits at 30, 60, 75, 90, 105 and 120 DAS) with entire dose of P (60 kg/ha) and K (60 kg/ha) coupled with foliar application of KNO_3 (2%) (3 sprays on 15 October, 1 November and 31 November) significantly increased the seed cotton yield (25.4 kg/ha), gross returns (₹56.2×10^3/ha), net returns (₹27.8×10^3/ha) and benefit: cost ratio (1.98). The next treatment in the order was recommended nitrogen (120 kg/ha) into 7 splits (10% as basal, remaining 90% in equal splits at 30, 60, 75, 90, 105 and 120 DAS) with entire dose of P (60 kg/ha) and K (60 kg/ha) coupled with soil application of $MgSO_4$@ 25 kg/ha alone recorded increased seed-cotton yield (25.2 kg/ha), gross returns (₹55.7×10^3/ha), net returns (₹27.7×10^3/ha), and benefit: cost ratio (1.99).

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