Assessing the Contribution of Nutrients to Maximize Transgenic Cotton Yields in Vertisols of Northern Karnataka

By D. P. Biradar, Y. R. Aladakatti, M. A. Basavanneppa, D. Shivamurthy, and T. Satyanarayana

Although cotton production in India increased after the introduction of transgenic cotton, its productivity is still very low when compared both to its potential yield within India and the world's average. This article indicates that the principles of site-specific nutrient management (SSNM) offer a good opportunity to reverse this trend.

Cotton is one of the most important fiber and cash crops of India and plays a dominant role in the industrial and agricultural economy of the country. India has the largest area cultivated under cotton at 9.5 million (M) ha, which constitutes 27% of world's area. As a result, India has emerged as the world's second largest producer of cotton—estimated at 31 M bales during 2010-11. Cotton production in India increased from 470 to 525 kg lint/ha with the first introduction, and increased adoption, of transgenic Bt cotton between 2004 and 2008. After which, Bt cotton area declined and productivity fell to 486 kg lint/ha during 2009-10.

In Karnataka, the total area under cotton is 3.9 lakh (390,000) ha with an average productivity of 392 kg lint/ha (Anonymous, 2009). In Northern Karnataka, area under cotton is of about 300,000 ha, out of which 70% is currently under Bt cotton, and this is expected to increase in the coming years. Though the yield potential for Bt cotton is high, the average productivity of cotton in the State is very low at 231 kg lint/ha. Also there is apprehension that the quality of fiber from transgenic cotton is poor, and therefore, of lower market value. Imbalanced nutrition could be one of the reasons for low productivity and poor fiber quality, but information on nutrient management of transgenic cotton is very limited in the State. This research project was initiated to explore the possibility of improving productivity of transgenic cotton through yield target-based fertiliser application following the principles of SSNM in the black cotton soils of Northern Karnataka.

Two experimental sites were selected, located at the main agricultural research station of the University of Agricultural Sciences in Dharwad, Karnataka and at Agricultural Research Station in Siruguppa, Karnataka. Field experiments were conducted for two consecutive years under rainfed and irrigated conditions, during the *Kharif* seasons of 2009-10 and 2010-11, respectively. The soil at Dharwad was slightly alkaline (pH 7.4) and the EC measured in 1:2.5 soil:water suspension was non-saline (0.4 dS/m). Available N, P_2O_5, and K_2O contents were low (195 kg/ha), medium (18.8 kg/ha), and high (333 kg/ha) with sufficient available Ca, Mg, S, Zn and Fe contents, the values being 25, 4, 36, 1, and 3 ppm, respectively. The experimental soil at Siruguppa was alkaline (pH 8.5), non-saline EC (0.4 dS/m), low organic C (0.41%), medium available P_2O_5 (21.2 kg/ha), and high available K_2O (430 kg/ha).

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; S = sulphur; B = boron; Fe = iron; Zn = zinc; C = carbon; Bt = *Bacillus thuringiensis* (a gram-positive, soil-dwelling bacterium whose toxins are made to express in crops to make crops tolerant to insect-pests); DAS = days after sowing; $CaSO_4$ = calcium sulphate; $MgSO_4$ = magnesium sulphate; $FeSO_4$ = iron sulphate $ZnSO_4$ = zinc sulphate; ppm = parts per million; EC = electrical conductivity.

Before the start of the experiment, the targeted seed cotton yield was set at 3 t/ha considering the available information on nutrient uptake and soil test values from the experimental sites. The experiment was set up in a randomised block design with 11 treatments including an absolute control and three replications. An omission plot technique was adopted to assess different nutrient contributions towards yield of transgenic cotton. The treatments (**Table 1**) consisted of complete SSNM treatment (T_1), nine nutrient omission plots for N, P, K, Ca, Mg, S, Zn, Fe, and B (T_2 to T_{10}) and a control (T_{11}) with no nutrient application. Both locations used the cotton hybrid RCH-2Bt (BG-II). All nutrients were applied at sowing with the exception of N and K, which were applied in three splits (i.e. 25% basally, 50% at 30 DAS, and 25% at 60 DAS). Uniform cultural practices and plant protection measures were adopted in all treatments. The observations on growth and yield parameters were recorded at both the locations and the average of 2 years data is reported in this paper. We also calculated gross returns, net returns, and benefit-to-cost (B:C) ratios from the average prevailing cotton price during the experimental year.

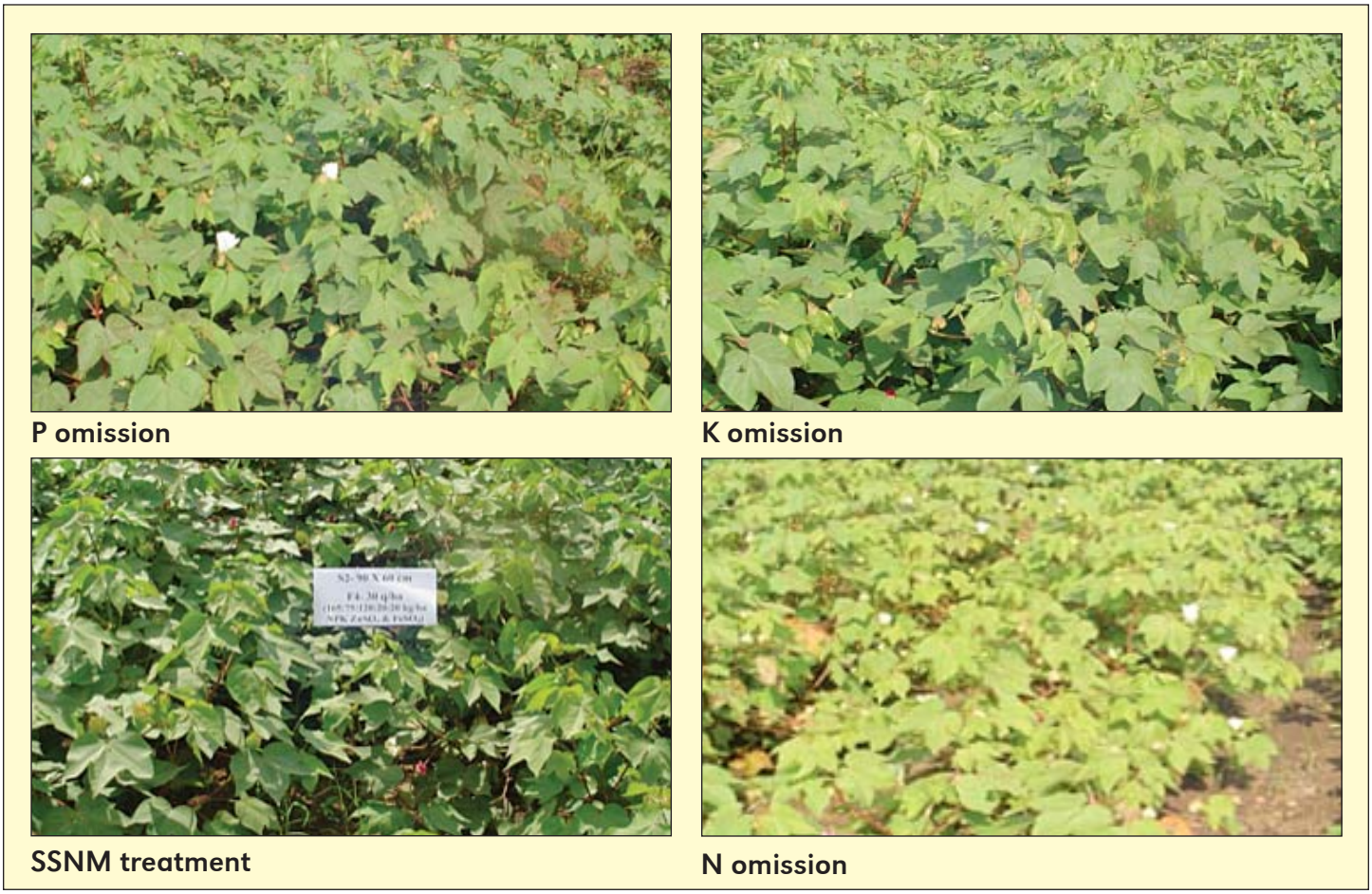
Table 1. Treatment details imposed in the experiment.

Treatment	Description
T_1 - SSNM†	• 165-75-120 kg N-P_2O_5-K_2O/ha • 20 kg/ha $CaSO_4$ and $MgSO_4$ • 10 kg S/ha • 20 kg/ha $ZnSO_4$ and $FeSO_4$ • 0.1% B (two foliar sprays)
T_2 - N omission	T_1 – N
T_3 - P omission	T_1 – P
T_4 - K omission	T_1 – K
T_5 - Ca omission	T_1 – Ca
T_6 - Mg omission	T_1 – Mg
T_7 - S omission	T_1 – S
T_8 - Zn omission	T_1 – Zn
T_9 - Fe omission	T_1 – Fe
T_{10} - B omission	T_1 – B
T_{11} - Control	No fertiliser

† Designed for a 3 t/ha yield target.

Results

Omission of nutrients had a significant effect on different growth parameters of transgenic cotton (**Table 2**). At both locations, N omission drastically reduced plant height compared to the effect of omitting other primary and micronutrients. Next to the control, the number of monopodial branches and the number of bolls per plant were considerably low under N omission at both locations signifying the importance of N in promoting the growth and yield attributing parameters of



The trials with transgenic (Bt) cotton indicated that N was the most significant yield-limiting factor, followed by K, then P.

transgenic cotton. Omission of N recorded the lowest number of sympodial per plant (19.8) compared to other treatments at Dharwad.

Nutrient application for a yield target of 3 t/ha resulted in a seed cotton yield of 3,392 and 2,383 kg/ha at Dharwad and Siruguppa, respectively (**Table 3**). At these yield levels, higher net returns of INR 68,970/ha, with a B:C of 3.5, were observed at Dharwad compared to returns of INR 42,141/ha and a B:C of 2.6 at Siruguppa (**Table 4**). The difference in targeted and measured yields in Siruguppa might be because of the late sowing (28 days) caused by a late release of canal water during the first year. This undermined the fact that time of sowing in addition to better nutrient management plays an important role in attaining the desired yield targets. Omission of nutrients caused a yield loss that varied between 2 to 41% at Dharwad and yield loss was the highest due to exclusion of N (41%) followed by K (20%), P (11%), and Zn (8%) omission. Omission of other secondary and micronutrients had little impact on yield loss. The data clearly indicates that providing optimum rates of NPK nutrients is important at Dharwad where cotton is grown under rainfed conditions. Zhang et al. (2008) also reported that N was the first yield-limiting factor in cotton followed by P and K based on a 5 year omission plot study.

Yield loss at Siruguppa due to nutrient omission varied between 1 to 17%, with the yield loss due to N omission being highest at 17%, and losses of 15% each was observed due to omission of Ca, Mg, S, and Fe, respectively (**Table 3**). This clearly suggests the need to apply secondary and micronutrients in balanced proportions along with N for growing transgenic cotton under irrigated conditions. The field research demonstration in Northern Karnataka on SSNM in cotton also reported similar observations (Biradar et al., 2006).

The treatment with N omitted, as expected, gave the least net returns per ha of INR 34,663 and 33,487 and low B:C values of 2.5 and 2.4 at Dharwad and Siruguppa, respectively. These were about 50 and 13% less than those obtained with SSNM applied for the yield target of 3 t/ha (i.e. INR 68,970/ha and INR 42,141/ha). Omission of K also resulted in a 25% reduction in net income (INR 52,624/ha) at Dharwad. Omission of other primary and micronutrients did not impact net returns to a great extent at both locations (**Table 4**). Efforts to test and confirm these results at the farmer participatory level at different locations within the cotton-growing area, and to disseminate these results to farmers through training programmes, are also being considered as a part of the study.

Conclusion

Omission of N reduced the seed cotton yield and net income by about 41 and 50% followed by omission of K and P. Omission of N also resulted in lower net income compared to other nutrients. However, omission of secondary nutrients such as Ca, Mg, S, and micronutrients such as Zn, Fe, and B had no drastic negative effect on cotton yields. Hence, N followed by K and P were the major nutrients contributing to higher yield of Bt cotton. The delayed sowing, erratic rainfall, late release of canal water and non-availability of irrigation water during critical crop growth stages could lower the yields of cotton in spite of providing better nutrient management, therefore

The research cooperators visiting the cotton experimental site at Agricultural Research Station, Siruguppa (Karnataka), (From L to R): Dr. M. Basavanneppa, Dr. D.P. Biradar, Dr. T. Satyanarayana, Dr. Y.R. Aladakatti, and Dr. Rajakumar.

Table 2. Effect of SSNM and nutrient omission on different growth parameters of transgenic cotton.

	Dharwad				Siruguppa			
Treatment	Plant height, cm	No. of monopodia per plant	No. of sympodia per plant	No. of bolls per plant	Plant height, cm	No. of monopodia per plant	No. of sympodia per plant	No. of bolls per plant
T_1 - SSNM	122.2	4.2	25.7	57.3	131.5	1.3	25.9	44.5
T_2 - N omission	96.7	3.6	19.8	27.3	121.9	1.6	23.6	32.5
T_3 - P omission	110.5	4.1	23.9	50.7	122.8	1.6	24.3	36.7
T_4 - K omission	108.5	3.8	20.6	38.5	124.3	1.7	23.5	40.6
T_5 - Ca omission	110.1	4	22.5	48.4	124.2	1.7	24.8	39.1
T_6 - Mg omission	115	4.1	23.1	48.8	129.8	1.6	22.3	40.8
T_7 - S omission	117.1	4.2	24.4	55.3	130	1.5	24.8	44.3
T_8 - Zn omission	113.3	4.1	21.9	46.4	132.3	1.7	24.2	41.5
T_9 - Fe omission	114.4	4.2	22.5	54.2	133	1.7	25.2	40.6
T_{10} - B omission	118.4	4.2	24.7	56.6	132.7	1.7	26.1	41.9
T_{11} - Control	80.5	3.1	17.2	24.9	111.5	1.3	22.6	21.6
CD (p = 0.05)	10.5	0.59	2.7	9.5	5.4	0.3	NS	3.7

Table 3. Effect of SSNM and different nutrient omission treatments on transgenic seed cotton yield.

	Dharwad			Siruguppa		
Treatment	Yield, kg/ha	Yield response, kg/ha	Yield loss, %	Yield, kg/ha	Yield response, kg/ha	Yield loss, %
T_1 - SSNM	3,392	-	-	2,383	-	-
T_2 - N omission	2,003	1,389	41	1,981	402	17
T_3 - P omission	3,018	374	11	2,090	293	12
T_4 - K omission	2,727	665	20	2,085	298	13
T_5 - Ca omission	3,285	107	3	2,016	367	15
T_6 - Mg omission	3,291	101	3	2,016	367	15
T_7 - S omission	3,333	59	2	2,026	357	15
T_8 - Zn omission	3,134	258	8	2,170	213	9
T_9 - Fe omission	3,230	162	5	2,036	347	15
T_{10} - B omission	3,326	66	2	2,369	14	1
T_{11} - Control	1,552	1,840	54	1,030	1,353	57
CD (p = 0.05)	71	-	-	27	-	-

due care has to be taken on the said factors in ensuring better yields of transgenic cotton. BCSA

Dr. D.P. Biradar (e-mail: dpbiradar@yahoo.com) is Professor and Dr. Y.R. Aladakatti (e-mail: yraladakatti@rediffmail.com) is Senior Scientist, Department of Agronomy, University of Agricultural Sciences, Dharwad. Dr. M.A. Basavanneppa (e-mail: basavanneppa6@gmail.com) is Assistant Agronomist (Cotton), Agricultural Research Station, Siruguppa. Mr. D. Shivamurthy (e-mail: shivaagron@gmail.com) assisted in the project as research scholar. Dr. T. Satyanarayana (e-mail: tsatya@

ipni.net) is Deputy Director, IPNI South Asia Programme, South India and Sri Lanka.

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Table 4. Effect of SSNM and different nutrient omission treatments on economics of transgenic cotton.

	Dharwad			Siruguppa		
Treatment	Gross returns, INR/ha	Net returns, INR/ha	B:C	Gross returns, INR/ha	Net returns, INR/ha	B:C
T_1 - SSNM	96,676	68,970	3.5	67,925	42,141	2.6
T_2 - N omission	57,080	34,663	2.5	56,449	33,487	2.4
T_3 - P omission	86,020	61,049	3.4	59,555	36,,306	2.6
T_4 - K omission	77,705	52,624	3.1	59,432	35,353	2.5
T_5 - Ca omission	93,618	67,381	3.6	57,456	33,791	2.4
T_6 - Mg omission	93,794	67,141	3.5	57,456	33,391	2.4
T_7 - S omission	94,984	67,576	3.5	57,750	33,009	2.3
T_8 - Zn omission	89,321	62,860	3.4	61,854	37,203	2.5
T_9 - Fe omission	92,043	65,344	3.4	58,017	33,702	2.4
T_{10} - B omission	94,795	67,954	3.5	67,507	42,460	2.7
T_{11} - Control	44,237	32,007	3.6	29,345	17,821	2.5
CD (p = 0.05)	20,216	18,443	0.57	7,596	6,930	NS

Price details (INR): N = 11/kg, P_2O_5 = 24/kg, K_2O = 8/kg, S = 15/kg, $CaSO_4$ = 60/kg, $ZnSO_4$ = 30/kg, $MgSO_4$ = 40/kg, $FeSO_4$ = 30/kg, Borax (B) = 70/kg, Seed cost = 1,665/kg, Seed market price = 28.50/kg.

A Guide to Identifying and Managing Nutrient Deficiencies in Cereal Crops

A new field guide has been developed by the IPNI South Asia Program in cooperation with the International Maize and Wheat Improvement Center (CIMMYT). It is a 50-page booklet (8 1/2 x 11 in. size, wire-o bound) designed to describe the appearance and underlying causes of nutrient deficiencies in maize, wheat, rice, sorghum, pearl millet, and barley. Tips are also included on how they might be prevented or remedied. Hundreds of excellent deficiency photographs provided by the authors and IPNI will allow the user of this field guide to understand the development of nutrient deficiency symptoms through the growth stages of the crop.

Details on obtaining a copy of this booklet can be found at the IPNI on-line store at: http://info.ipni.net/nutridefcereal