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EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON MACRO AND MICRO NUTRIENT CONTENT AND UPTAKE IN *BT* COTTON (*GOSSYPIUM HIRSUTUM* L.) GROWN ON *VERTISOLS*

Vidhi D. Mistry[1]*, P.S. Patel[2], M.M. Patel[3], A.P. Italiya[4] and H.R. Ramani[3]

[1]Department of Soil Science and Agricultural Chemistry, NMCA, NAU, Navsari, Gujarat, India.

[2]Cotton Research Sub Station, NAU, Achhalia, Bharuch, Gujarat, India.

[3]Main Cotton Research Station, NAU, Surat, Gujarat, India.

[4]Soil and Water Management Research Unit, NAU, Navsari, Gujarat, India.

*Corresponding author E-mail : hiteshramani2007@gmail.com

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ABSTRACT

A field experiment was conducted during *Kharif* 2024–25 at Main Cotton Research Station, Navsari Agricultural University, Surat, to evaluate the effect of integrated nutrient management on macro and micronutrient content and uptake of *Bt* cotton (*G. Cot. Hy-10*) grown on *Vertisols*. The soil of experimental field was clayey in texture, low in organic carbon content (0.44%) and available nitrogen (221.40 kg/ha), medium in available phosphorus (32.16 kg/ha) and high in available potassium (570.59 kg/ha) with pH 7.78, EC 0.42 dS/m and BD 1.34 Mg/m^3. The experiment consisted of ten treatments *i.e.*, T_1 (100% RDF), T_2 (100% RDN through FYM), T_3 (100% RDN through Biocompost), T_4 (75% RDF + 25% RDN through FYM), T_5 (75% RDF + 25% RDN through Biocompost), T_6 (75% RDF +25% RDN through FYM + Green manuring with sunhemp), T_7 (75% RDF + 25% RDN through Biocompost + Green manuring with sunhemp), T_8 (50% RDF + 25% RDN through FYM + 25% RDN through Neemcake + Green manuring with sunhemp), T_9 (50% RDF + 25% RDN through Biocompost + 25% RDN through Neemcake + Green manuring with sunhemp), T_{10} (Absolute Control) and was laid out in Randomized Block Design with three replications. Results revealed that nitrogen and potassium content in seed and stalk were significantly influenced by treatments, whereas phosphorus content remained non-significant. The integrated application of 75% RDF + 25% RDN through biocompost along with green manuring using sunhemp (T_7) recorded the highest nitrogen content in seed (3.10%) and stalk (0.85%) and potassium content in seed (0.60%) and stalk (1.29%). The maximum uptake of nitrogen, phosphorus and potassium in seed (74.18, 16.24 and 14.50 kg ha^{-1}, respectively) and stalk (50.91, 10.91 and 76.96 kg ha^{-1}, respectively) was also recorded under T_7 . Iron content in seed (56.81 mg kg^{-1}) and stalk (156.48 mg kg^{-1}) and its uptake were significantly improved under integrated nutrient management, while Mn, Zn and Cu content and uptake showed non-significant variation among treatments. Absolute control recorded the lowest macro and micronutrient content and uptake. The study concludes that integrated use of organic and inorganic nutrient sources enhances nutrient uptake and supports balanced nutrition in *Bt* cotton under south Gujarat conditions.

Key words : Bt cotton, Organic sources, Nutrient content, Nutrient uptake, Macronutrients, Micronutrients.

Introduction

Cotton (*Gossypium* spp.) is a member of the *Malvaceae* family and is renowned as the 'King of Fiber' and White Gold across the world. It is one of the most important fibre and cash crop of India and Gujarat. Among cultivated species, *Gossypium hirsutum* represents 88% of hybrid cotton production in India and all current *Bt* cotton hybrids belong to this species. *Bt* cotton hybrids are genetically modified with *Bacillus thuringiensis* (*Bt*) genes to enhance yield and provide resistance against pests (Kathage and Qaim, 2012).

In the world cotton scenario, China is the leading producer of cotton with 56.00 lakh tones equivalent to 329 lakh bales of 170 kg. India is the second largest producer of cotton with 53.85 lakh tones equivalent to 316 lakh bales of 170 kg. India is the leading country in

terms of cotton cultivation, covering around 125 lakh hectares, approximately 39% of the world's cotton-growing area and produces 22% of the global cotton production. Rainfed agriculture plays an important role in contributing to world food security. In India, area under rainfed agriculture is about 85 m. ha representing 60% of net cultivated area and supports 40% population of the country. Apart from erratic rainfall, soils are highly degraded physically, chemically and biologically (Sankar *et al*., 2011; Sharma *et al*., 2005; Vittal *et al*., 2003).

Cotton production and productivity can be increased only through enhanced soil fertility, which can be sustained if nutrients removed from the soil are replenished. Supplying the entire quantity of nutrients through chemical fertilizers may not be feasible due to rising prices. Combination of imbalanced fertilization and no recycling of crop residues have deteriorated soil quality leading to low yields in rainfed areas (Campbell *et al*., 2001; Roldan *et al*., 2003; Sharma *et al*., 2008).

Organic manures play an important role in improving soil physico-chemical properties and regulating nutrient release for better plant growth (Tisdale *et al*., 1985). Farmyard manure (FYM) is a valuable organic source that supplies essential macro and micronutrients through biological decomposition and enhances crop yield by improving soil fertility. Compost application improves soil structure, water-holding capacity, nutrient retention and microbial activity, leading to sustainable soil health and higher productivity (Smith, 1992). Green manuring with leguminous crops such as sunhemp and dhaincha enriches soil nitrogen through biological fixation and adds organic matter, thereby improving soil fertility. Integrated use of organic sources, crop residues and inorganic fertilizers enhances soil physical, chemical and biological properties, increases organic carbon content and ensures sustainable crop production (Chandel *et al*., 2017). Neem-based products are eco-friendly and effective in cotton pest management and support integrated pest management practices. Overall, integrated nutrient management improves soil quality, nutrient availability and crop productivity, with soil organic carbon being a key indicator of long-term agricultural sustainability (Doran and Parkin, 1994).

Evaluating both nutrient content (%) in plant tissues and total nutrient uptake (kg/ha) is essential to understand the actual removal of nutrients from the soil and to optimize nutrient management for sustainable cotton production. Therefore, the present study was undertaken to assess the effect of different organic sources on macro and micronutrient content and uptake in *Bt* cotton, with the aim of identifying treatments that improve plant nutrition and support sustainable agriculture.

Materials and Methods

Experimental site and crop details

The experiment was conducted at Main Cotton Research Station, Navsari Agricultural University, Surat during *Kharif* 2024–25 using *Bt* cotton *G. Cot. Hy-10 (BG-II)*. Research station is located at 20° 12' North latitude and 72° 52' East longitude at an altitude of 12 m above mean sea level. The crop was sown at 120 × 45 cm spacing with gross plot 6.00 × 6.30 m and net plot 3.60 × 5.40 m.

Soil characteristics

The experimental soil was a *Vertisol* (*Typic Haplichromerts*) belonging to the Surat soil series, commonly known as deep black soil. The soil was clayey in texture, slightly alkaline (pH 7.78) with normal electrical conductivity (0.42 dS m^{-1}). It contained low organic carbon (0.44%) with a bulk density of 1.34 Mg m^{-3}. The soil was low in available nitrogen (221.40 kg ha^{-1}), medium in available phosphorus (32.16 kg ha^{-1}) and high in available potassium (570.59 kg ha^{-1}). Available Fe, Mn, Zn and Cu were 9.33, 4.95, 1.32 and 2.16 mg kg^{-1}, respectively.

Experimental design and treatments

The experiment was laid out in a randomized block design with ten treatments and three replications. The treatments consisted of different combinations of chemical fertilizers and organic nutrient sources *viz.*, T_1 – 100% recommended dose of fertilizers (RDF); T_2 – 100% recommended dose of nitrogen (RDN) through farmyard manure (FYM); T_3 – 100% RDN through biocompost; T_4 – 75% RDF + 25% RDN through FYM; T_5 – 75% RDF + 25% RDN through biocompost; T_6 – 75% RDF + 25% RDN through FYM along with green manuring using sunhemp; T_7 – 75% RDF + 25% RDN through biocompost along with green manuring using sunhemp; T_8 – 50% RDF + 25% RDN through FYM + 25% RDN through neem cake along with green manuring using sunhemp; T_9 – 50% RDF + 25% RDN through biocompost + 25% RDN through neem cake along with green manuring using sunhemp and T_{10} – absolute control.

Organic manures and fertilizers

The recommended dose of fertilizer (240:40:00 NPK kg ha^{-1}) was supplied through urea and SSP as per treatments. FYM, biocompost, neem cake and sunhemp were analyzed for moisture and nutrient composition before application and applied on nitrogen equivalent basis as basal dose. Sunhemp (*Crotalaria juncea*) was

incorporated at 50% flowering stage. The chemical composition of organic sources is presented in Table 1.

Table 1 : Chemical compositions of different organic sources.

S. no.	Parameters	Organic sources			
		FYM	Bio compost	Neem cake	Sunhemp
1.	Moisture content (%)	55.40	46.90	8.60	82.83
2.	N (%)	0.61	1.24	4.50	0.51
3.	P (%)	0.31	1.09	0.70	0.19
4.	K (%)	0.57	1.19	1.72	0.33
5.	Fe (mg/kg)	1025	2164	1422	394
6.	Mn (mg/kg)	132	216	95	168
7.	Zn (mg/kg)	32	58	54	53
8.	Cu (mg/kg)	15	34	28	21

Chemical analysis of plant and nutrient uptake

Plant samples of *Bt* cotton (seed cotton and stalk separately) collected at harvest were oven dried, ground to fine powder and stored in polythene bags for chemical analysis.

Nitrogen was estimated by Kjeldahl's method, phosphorus by the Vanadomolybdophosphoric acid yellow colour method, potassium by flame photometry as described by Jackson (1973). The micronutrients Fe, Mn, Zn and Cu were determined using Atomic Absorption Spectrophotometry following the procedure outlined by Zasoski and Burau (1977).

Uptake of nutrients was calculated as per standard procedure by multiplying the nutrient content with the corresponding seed cotton and stalk yield.

Statistical analysis

The experimental data were statistically analyzed using analysis of variance (ANOVA) appropriate to randomized block design as described by Panse and Sukhatme (1985). The treatment means were compared using critical difference (CD) at 5 per cent level of significance.

Results and Discussion

Effect of different treatments on macro nutrient content of *Bt* cotton seed and stalk

The content of nitrogen, phosphorus and potassium in seed and stalk of *Bt* cotton as influenced by different organic nutrient management treatments is presented in Table 2. Nitrogen content in seed and stalk was significantly influenced by the treatments. Treatment T_7 (75% RDF + 25% RDN through biocompost along with green manuring using sunhemp) recorded significantly higher nitrogen content in seed (3.10%) and stalk (0.85%), which remained statistically at par with T_6 (75% RDF + 25% RDN through FYM along with green manuring using sunhemp). The lowest nitrogen content in both seed and stalk was recorded under the absolute control (T_{10}). Phosphorus content in seed and stalk was not significantly affected by the treatments. However, higher phosphorus content in seed (0.68%) and stalk (0.18%) was observed under T_7, while the lowest values were recorded under T_{10}. Potassium content in seed and stalk was significantly influenced by different treatments. Treatment T‡ recorded significantly higher potash content in seed (0.60%) and stalk (1.29%), which was statistically at par with T_6, T_5 and T_4. The lowest potassium content in seed (0.32%) and stalk (0.69%) was recorded under the absolute control (T_{10}).

Table 2 : Effect of different treatments on N, P, K content (%) of Bt cotton seed and stalk.

Treatments	Nutrient content (%) in seed			Nutrient content (%) in stalk		
	N	P	K	N	P	K
T_1	2.82	0.63	0.45	0.73	0.17	0.87
T_2	2.61	0.60	0.48	0.54	0.15	1.01
T_3	2.68	0.61	0.49	0.55	0.16	1.09
T_4	2.86	0.63	0.55	0.76	0.17	1.21
T_5	2.90	0.64	0.57	0.79	0.17	1.24
T_6	2.97	0.67	0.59	0.82	0.18	1.26
T_7	3.10	0.68	0.60	0.85	0.18	1.29
T_8	2.75	0.62	0.50	0.66	0.16	1.11
T_9	2.77	0.62	0.52	0.68	0.16	1.17
T_{10}	2.24	0.55	0.32	0.41	0.13	0.69
SEm ±	0.04	0.02	0.01	0.01	0.01	0.03
CD at 5%	0.13	NS	0.04	0.05	NS	0.09
CV (%)	2.88	6.62	4.81	4.86	10.25	5.16

Thimmareddy *et al*. (2013) reported that green manuring with sunhemp and dhaincha increased the availability of nitrogen, phosphorus and potassium due to direct addition of nutrients and enhanced microbial activity responsible for mineralization of organically bound forms, particularly nitrogen. Application of FYM, vermicompost and green leaf manures has been reported to enhance nitrogen mineralization as a result of increased microbial and enzymatic activity. Vidyavathi *et al*. (2012) also reported higher potassium content in cotton seed and stalk with the application of organic inputs such as FYM, vermicompost and green manures, attributed to the release of organic acids during decomposition, which

Table 3 : Effect of different treatments on Fe, Mn, Zn, Cu content (mg/kg) of *Bt* cotton seed and stalk.

Treatments	Micro nutrient content (mg/kg) in seed				Micro nutrient content (mg/kg) in stalk			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
T_1	41.42	21.24	37.25	7.01	115.08	42.93	18.31	11.00
T_2	45.66	22.95	39.01	6.87	124.76	43.41	18.86	10.82
T_3	47.76	24.04	44.32	7.42	134.60	48.59	20.35	11.45
T_4	46.94	23.57	43.55	7.04	132.98	46.29	19.23	11.11
T_5	48.55	24.26	45.26	7.59	140.07	49.15	21.02	11.59
T_6	52.41	25.71	46.49	8.15	149.56	50.28	22.50	12.49
T_7	56.81	26.88	46.87	8.46	156.48	51.84	22.95	12.66
T_8	49.98	25.00	45.88	7.99	144.89	50.02	22.39	11.96
T_9	55.90	26.25	46.50	8.39	152.00	51.76	22.73	12.52
T_{10}	37.08	20.12	34.85	6.60	103.75	39.73	15.26	10.31
SEm±	1.44	1.36	2.77	0.43	5.57	3.12	1.58	0.53
CD at 5%	4.31	NS	NS	NS	16.68	NS	NS	NS
CV (%)	5.16	9.87	11.19	9.93	7.12	11.42	13.45	7.95

improved potassium solubilization and availability. Similar findings were also reported by Sangshetty and Babalad (2011) and Deshmukh *et al.* (2019).

Effect of different treatments on micro nutrient content of *Bt* cotton seed and stalk

The content of micro nutrients in seed and stalk of *Bt* cotton as influenced by different organic nutrient management treatments is presented in Table 3. The data revealed that iron (Fe) content in seed was significantly influenced by different treatments. Treatment T_7 (75% RDF + 25% RDN through biocompost along with green manuring using sunhemp) recorded significantly higher Fe content in seed (56.81 mg kg^{-1}), which was statistically at par with T_9 (55.90 mg kg^{-1}) and T_6 (52.41 mg kg^{-1}). The lowest Fe content in seed (37.08 mg kg^{-1}) was recorded under the absolute control (T_{10}). However, manganese, zinc and copper contents in seed were not significantly affected by the treatments, though higher values were consistently recorded under T_7, while the lowest values were observed under T_{10}. Similarly, Fe content in stalk was significantly higher under T_7 (156.48 mg kg^{-1}), which remained statistically at par with T_9 (152.00 mg kg^{-1}), T_6 (149.56 mg kg^{-1}) and T_8 (144.89 mg kg^{-1}). The lowest Fe content in stalk (103.75 mg kg^{-1}) was recorded under T_{10}. The contents of Mn, Zn and Cu in stalk were not significantly influenced by the treatments; however, higher values were observed under T_7, while the lowest were recorded in the absolute control.

The increase in micronutrient content in cotton seed and stalk can be attributed to improved uptake and translocation supported by integrated nutrient management practices. Organic amendments like FYM, biocompost and green manures enhance microbial activity and nutrient solubility, leading to greater availability of micronutrients. Similar findings reported by Vidyavathi *et al.* (2012) and Deshmukh *et al.* (2019).

Effect of different treatments on macro nutrient uptake of *Bt* cotton seed and stalk

The uptake of nitrogen, phosphorus and potassium in seed and stalk of *Bt* cotton as influenced by different organic nutrient management treatments is presented in Table 4. The uptake of nitrogen, phosphorus and potassium in seed of *Bt* cotton was significantly influenced by different nutrient management treatments. Treatment T_7 (75% RDF + 25% RDN through biocompost + green manuring using sunhemp) recorded the highest nitrogen uptake (74.18 kg/ha), which was statistically at par with T_6 (68.50 kg/ha). Similarly, phosphorus uptake in seed was highest under T_7 (16.24 kg/ha), remaining at par with T_6 (15.40 kg/ha) and T_5 (14.47 kg/ha). Potassium uptake in seed was also significantly higher under T_7 (14.50 kg/ha), statistically at par with T_6 (13.65 kg/ha) and T_5 (13.03 kg/ha). The lowest nutrient uptake for N, P and K was consistently recorded under the absolute control (T_{10}) with values of 24.41, 6.08 and 3.49 kg/ha, respectively.

Vidyavathi *et al.* (2012) reported that enhanced crop response under integrated nutrient management was primarily due to improved nutrient availability in the soil, complemented by inputs from FYM and inorganic fertilizers. Chemical sources provide readily available N, P and K during the early growth stages. While, organic sources ensure a gradual nutrient release during later stages, thus supporting sustained crop development and nutrient uptake. Nutrient uptake is dependent on nutrient concentration and dry matter yield of plant reported by

Table 4 : Effect of different treatments on N, P, K uptake (mg/kg) of *Bt* cotton seed and stalk.

Treatments	Nutrient uptake (kg/ha) in seed			Nutrient uptake (kg/ha) in stalk		
	N	P	K	N	P	K
T_1	58.68	13.25	9.36	38.58	8.90	45.74
T_2	37.00	8.63	6.95	20.79	5.82	38.56
T_3	41.52	9.53	7.65	22.09	6.43	43.91
T_4	63.00	13.97	12.08	40.78	9.04	64.53
T_5	65.57	14.47	13.03	43.21	9.30	68.04
T_6	68.50	15.40	13.65	46.52	10.11	70.97
T_7	74.18	16.24	14.50	50.91	10.91	76.96
T_8	48.52	10.91	8.80	29.87	7.36	50.42
T_9	52.47	11.82	9.97	33.06	7.84	56.35
T_{10}	24.41	6.08	3.49	10.11	3.12	16.67
SEm±	2.33	0.74	0.51	1.57	0.37	3.10
CD at 5%	6.99	2.22	1.54	4.71	1.12	9.28
CV (%)	7.58	10.69	8.98	8.12	8.27	10.09

Thimmareddy *et al.* (2013) in *Bt* cotton. The additional uptake of nitrogen and phosphorus by cotton was contributed by the incorporation of dhaincha as green manure, as this legume undergoes biological nitrogen fixation through symbiotic association with *Rhizobium* bacteria in root nodules. Upon decomposition, the organic matter from dhaincha releases nitrogen and other nutrients, which are subsequently mineralized into plant-available forms. In the case of potassium, the increase in uptake may be attributed to greater K availability enhanced by the priming effect, in addition to direct release from decomposed green manure reported by Marimuthu *et al.* (2014). Similar results were also obtained by Satyanarayana Rao and Janawade (2009); Babaria *et al.* (2010); Wagh *et al.* (2016); Deshmukh *et al.* (2019); Meena *et al.* (2019) and Vani *et al.* (2021).

Effect of different treatments on micro nutrient uptake of Bt cotton seed and stalk

The uptake of micro nutrients in seed and stalk of *Bt* cotton as influenced by different organic nutrient management treatments is presented in Table 5. Treatment T_7 (75% RDF + 25% RDN through biocompost + green manuring using sunhemp) recorded the highest Fe uptake (135.56 g/ha), which was significantly higher than all other treatments. Manganese and copper uptake in seed were also higher under T_7(64.31 and 20.20 g/ha), remaining statistically at par with T_6 (59.07 and 18.80 g/ha) and T_5 (54.78 and 17.17 g/ha), respectively. Zinc uptake in seed was maximum under T_7 (111.53 g/ha), statistically at par with T_6 (106.78 g/ha), T_5 (102.24 g/ha) and T_4 (95.79 g/ha). The lowest uptake of all micronutrients was consistently recorded under the absolute control (T_{10}).

Table 5 : Effect of different treatments on Fe, Mn, Zn, Cu uptake (g/ha) of *Bt* cotton seed and stalk.

Treatments	Micro nutrient uptake (g/ha) in seed				Micro nutrient uptake (g/ha) in stalk			
	Fe	Mn	Zn	Cu	Fe	Mn	Zn	Cu
T_1	86.24	44.24	77.47	14.57	602.69	224.85	95.72	57.64
T_2	65.27	32.93	55.71	9.85	474.59	165.11	71.83	41.19
T_3	74.20	37.35	68.82	11.47	540.56	195.16	81.73	45.97
T_4	103.27	51.84	95.79	15.46	707.27	246.27	102.19	59.06
T_5	109.65	54.76	102.24	17.17	766.54	268.93	115.07	63.44
T_6	120.43	59.07	106.78	18.80	841.06	282.71	126.56	70.26
T_7	135.56	64.31	111.53	20.20	929.47	308.66	136.90	75.19
T_8	88.04	44.19	81.02	14.09	657.42	226.65	102.76	54.26
T_9	105.85	49.71	88.20	15.89	731.88	250.02	109.68	60.35
T_{10}	39.99	21.76	37.44	7.18	256.59	97.90	37.26	25.55
SEm±	5.05	3.73	6.69	1.23	33.04	18.89	9.45	3.65
CD at 5%	15.13	11.18	20.05	3.68	98.93	56.58	28.31	10.94
CV (%)	9.43	14.05	14.06	14.72	8.79	14.44	16.73	11.44

Increment in micronutrients uptake by seed and stalk due to application of FYM, biocompost and green manuring increase the availability of micronutrients to plant which was directly affected nutrient uptake. The increase in micronutrients uptake might be due to the fact that application of organic manures decreases the soil pH and increases the availability of the plant available forms of micronutrients reported by Vidyavathi *et al.* (2012) and Deshmukh *et al.* (2019)

Conclusion

The present study demonstrated that integrated nutrient management significantly influenced macro and

micronutrient content and uptake in *Bt* cotton grown on *Vertisols*. Application of 75% RDF combined with 25% RDN through biocompost along with green manuring using sunhemp resulted in higher nitrogen and potassium content in seed (3.10% and 0.60%) and stalk (0.85% and 1.29%), respectively, while phosphorus content was not significantly affected by the treatments. The same treatment also recorded the highest uptake of N, P and K in seed (74.18, 16.24 and 14.50 kg ha^{-1}) and stalk (50.91, 10.91 and 76.96 kg ha^{-1}). Iron content and uptake in seed and stalk were significantly improved under integrated nutrient management, whereas Mn, Zn and Cu showed non-significant variation among treatments. Absolute control recorded the lowest macro and micronutrient content and uptake. Overall, partial substitution of chemical fertilizers with organic sources and green manuring improved nutrient uptake efficiency and ensured balanced nutrition of *Bt* cotton under *Vertisol* conditions of south Gujarat.

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