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Enhancing *Bt* cotton productivity through *in-situ* green Manuring, optimized irrigation regimes and micronutrient management in Vertisols of the Malaprabha command area

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Abstract
The study was undertaken to evaluate the effects of in-situ green manuring, irrigation regimes, and micronutrient management on yield, water use efficiency, and soil fertility status of Bt cotton grown in a Vertisol of the Malaprabha Command Area. A long-term factorial experiment was conducted from 2014- 15 to 2017- 18 at the AICRP on Irrigation Water Management Research Centre, Belavatagi, using a split-plot design. The experiment comprised three irrigation levels in the main plots, namely I1 and I2 at 0.8 and 0.6 IW/CPE ratios, respectively, and I3 based on critical growth stages. Sub-plots consisted of five nutrient management treatments: F1 (100% recommended dose of fertilizers with FYM at 10 t ha^{-1}), F2 (F1 plus one row of sunhemp grown between two rows of Bt cotton), F3 (F2 plus application of $ZnSO_4$ at 25 kg ha^{-1}, $FeSO_4$ at 25 kg ha^{-1}, and borax at 5 kg ha^{-1}), and F4 and F5 which included 75% and 50% RDF, respectively, along with FYM at 10 t ha^{-1}, biofertilizers, one row of sunhemp between Bt cotton rows, micronutrients ($ZnSO_4$, $FeSO_4$, and borax at the above rates), and maize stalk incorporation at 10 t ha^{-1}.
Pooled results indicated that irrigation level I1 (0.8 IW/CPE) recorded a significantly higher kapas yield (19.01 q ha^{-1}) compared to irrigation scheduled at critical stages (I3), which yielded 16.17 q ha^{-1}. Among nutrient management practices, F3 resulted in significantly higher kapas yield (21.65 q ha^{-1}) and water use efficiency (3.69 kg ha^{-1} mm^{-1}). Soil analysis data collected during 2016- 17 and 2017- 18 revealed no significant differences in soil pH and electrical conductivity; however, significant improvements were observed in organic carbon content and the availability of P_2O_5, K_2O, and zinc under integrated nutrient management treatments.

Keywords: WUE, IW/CPE ratio, In-situ, kapas yield

Introduction
Cotton is one of the most important commercial crops cultivated in India, accounting for nearly 39 per cent of global cotton production. Owing to its significant contribution to the national economy through exports of raw cotton and cotton-based products, it is often referred to as "White Gold." Despite its economic importance, the Indian cotton sector has experienced considerable fluctuations in recent years due to biotic and abiotic stresses, along with increasing competition from other crops.
During 2023- 24, cotton production in India was estimated at 323.11 lakh bales from an area of 125 lakh hectares, with an average productivity of 441 kg lint ha^{-1}, as reported by the Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, New Delhi. Compared to 2022- 23, the area under cotton declined by 3.67 per cent, while production decreased by 4.18 per cent. In Karnataka, Bt cotton occupies about 6.95 lakh hectares, with an annual production of 16.93 lakh bales and a productivity of 414 kg ha^{-1} (AICCIP Annual Report, 2023- 24).
Although the introduction of Bt cotton cultivars initially resulted in higher yields ranging from 4.0 to 5.0 t ha^{-1}, recent trends indicate yield stagnation or decline. This stagnation poses a serious concern for farmers due to rising production costs and shrinking profit margins, thereby warranting focused research and intervention. The major constraints contributing to low productivity of Bt cotton include its predominance under rainfed conditions, inadequate

Adoption of balanced nutrient management practices, suboptimal agronomic management, and moisture stress during critical crop growth stages. Efficient rainwater management through in situ agronomic practices such as furrow opening, intercropping, mulching, and incorporation of organic residues plays a crucial role in enhancing soil moisture conservation and sustaining cotton yields (Gokhale *et al*., 2012) [12]. Furthermore, intensive cultivation of high-yielding cotton varieties in deep and medium black soils often leads to deficiencies of secondary and micronutrients, adversely affecting crop productivity and soil health.

Cotton is predominantly cultivated in black soils, where a gradual decline in yield levels has been observed due to imbalanced nutrient management, continuous use of high-analysis fertilizers, and insufficient incorporation of organic matter. As cotton is a widely spaced crop, it offers considerable scope for the inclusion of green manure crops as intercrops without adversely affecting the main crop. Incorporation of green manure is an effective approach to improving soil physical, chemical, and biological properties. Long-term addition of crop residues enhances the availability of both macro- and micronutrients and contributes to the buildup of soil organic matter.

Intercropping systems, by disrupting monocropping practices, provide several agronomic and ecological benefits, including improved pest and weed suppression, reduced wind erosion, and enhanced water infiltration (Turkhede *et al*., 2017) [25]. Adequate availability of macro- and micronutrients is essential for optimum plant growth, and supplemental nutrient application results in yield improvement primarily when native soil nutrient levels are suboptimal (Ahmad *et al*., 2011) [2]. Micronutrients such as boron, manganese, iron, copper, zinc, and molybdenum play critical roles in plant physiological and biochemical processes, influencing growth, development, and productivity (Putra *et al*., 2012; Rab and Haq, 2012) [28, 19].

In view of these considerations, the present investigation was undertaken to assess the long-term effects of in-situ green manuring, irrigation regimes, and micronutrient management on yield, water use efficiency, and soil available nutrient status of Bt cotton.

Material and Methods

A field experiment was conducted at the Irrigation Water Management Research Centre (IWMRC), Belavatagi, during the kharif seasons from 2014- 15 to 2017- 18. The experimental soil was clayey in texture with an initial pH of 8.45, electrical conductivity of 0.29 dS m^{-1}, organic carbon content of 0.51 g kg^{-1}, available phosphorus (P_2O_5) of 16.00 kg ha^{-1}, and available potassium (K_2O) of 523.60 kg ha^{-1}. The experiment was laid out in a factorial arrangement using a split-plot design with three replications.

The main plot treatments consisted of three irrigation regimes, namely I_1 and I_2 scheduled at 0.8 and 0.6 IW/CPE ratios, respectively, and I_3 based on irrigation at critical crop growth stages. Sub-plot treatments included five nutrient management levels: F_1 (100% recommended dose of fertilizers along with FYM at 10 t ha^{-1}), F_2 (F_1 plus one row of sunhemp grown as an intercrop between two rows of Bt cotton), F_3 (F_2 plus application of $ZnSO_4$ at 25 kg ha^{-1}, $FeSO_4$ at 25 kg ha^{-1}, and borax at 5 kg ha^{-1}), and F_4 and F_5 comprising 75% and 50% RDF, respectively, supplemented with FYM at 10 t ha^{-1}, biofertilizers, one row of sunhemp between two rows of Bt cotton, micronutrients ($ZnSO_4$, $FeSO_4$, and borax at the above rates), and maize stalk incorporation at 10 t ha^{-1}.

Bt cotton was grown during the kharif season, while the green manuring crop sunhemp was sown as an intercrop between cotton rows and subsequently incorporated into the soil. Maize stalk residues were decomposed using a microbial decomposer culture and incorporated into the soil prior to sowing. Total water use was computed as the sum of effective rainfall and irrigation water applied during the crop period. Water use efficiency was calculated by dividing crop yield (kg ha^{-1}) by total water use (mm).

Results and Discussion

Effect of *in-situ* green manuring, irrigation regimes and micronutrients on growth parameters of *Bt* cotton in a Vertisol of Malaprabha Command Area

The pooled data for the period 2014- 15 to 2017- 18 presented in Table 1 illustrate the influence of irrigation regimes and integrated nutrient management (INM) practices on growth parameters of Bt cotton, including plant height, number of monopodial and sympodial branches per plant, and number of bolls per plant. The results revealed that plant height was significantly affected by both irrigation levels and nutrient management treatments.

Among the irrigation regimes, significantly taller plants (162.71 cm) were recorded under I_1 (0.8 IW/CPE ratio), followed by I_2 (0.6 IW/CPE ratio) with a plant height of 160.43 cm, while the lowest plant height (157.38 cm) was observed under irrigation scheduled at critical growth stages (I_3). With respect to nutrient management, treatment F_3 recorded significantly higher plant height (164.64 cm), followed closely by F_2 (163.97 cm), compared to the remaining treatments. Significant interaction effects between irrigation and nutrient management treatments were also observed.

The enhanced plant growth under micronutrient application may be attributed to improved uptake of major nutrients (N, P, and K), which in turn promoted better vegetative development. Micronutrients such as zinc, iron, manganese, copper, and particularly boron play vital roles in physiological and biochemical processes. According to Putra *et al*. (2012) [28], boron availability is directly related to stomatal morphology, conductance, and transpiration, thereby influencing overall plant growth. Adequate absorption and utilization of these micronutrients likely accelerated the growth attributes of Bt cotton.

Similarly, the number of sympodial branches per plant was significantly influenced by irrigation and nutrient management practices. The irrigation regime I_1 (0.8 IW/CPE ratio) recorded a significantly higher number of sympodials per plant (34.10) compared to other irrigation levels. Among nutrient treatments, F_3 resulted in the maximum number of sympodial branches (35.45), which was significantly superior to the remaining treatments. The increase in sympodial branches may be attributed to the availability of optimum nutrient levels that enhanced cell division and elongation, leading to greater lateral branching. These findings are in close conformity with the results reported by Biradar and Palled (2003) [4].

Overall, the improvement in growth parameters under integrated nutrient management practices may be attributed to the continuous and balanced supply of nutrients through organic amendments, improved nutrient retention, and reduced losses. The enhancement in soil organic matter content likely increased cation exchange capacity, facilitating better nutrient availability in synchrony with crop demand throughout the growing period.

Effect of *in-situ* green manuring, irrigation regimes and micronutrients on yield parameters, WUE and economics of *Bt* cotton in a Vertisol of Malaprabha Command Area

In the present investigation, the pooled data on number of bolls per plant, kapas yield of Bt cotton, water use efficiency, net returns, and benefit- cost ratio as influenced by different nutrient management practices are presented in Table 2. The complementary application of organic and inorganic nutrient sources along with in-situ green manuring, FYM, micronutrients, and maize stalk incorporation synergistically enhanced crop productivity while sustaining soil fertility.

An overview of the pooled data revealed that the number of bolls per plant was significantly influenced by both irrigation regimes and integrated nutrient management practices. Among the irrigation levels, I_1 scheduled at 0.8 IW/CPE ratio recorded a significantly higher number of bolls per plant, followed by I_2 at 0.6 IW/CPE ratio (36.55) and irrigation at critical growth stages (I_3) with 34.55 bolls per plant. With respect to nutrient management, integrated treatments exhibited significant differences, with treatment F_3 recording the highest number of bolls per plant (41.24), followed by F_2 (38.82). The interaction between irrigation level I_1 (0.8 IW/CPE ratio) and nutrient treatment F_3 also resulted in a significantly higher number of bolls per plant.

The increased number of bolls per plant may be attributed to enhanced formation of fruiting branches, which improved boll retention and productivity of Bt cotton. Improved soil fertility through balanced application of organic and inorganic nutrient sources, supplemented with micronutrients such as zinc, iron, and boron, likely contributed to enhanced boll retention. These findings are in agreement with the results reported by Rudragouda (2012) [20]. Furthermore, Imayavaramban *et al*. (2006) [14] reported that micronutrient-induced hormonal balance within the plant system reduces the shedding of flowers, squares, and bolls, thereby increasing boll retention.

Significantly higher kapas yield was recorded under the irrigation regime I_1 scheduled at 0.8 IW/CPE ratio (19.01 q ha^{-1}) compared to the other irrigation levels. Among the nutrient management treatments, F_3 produced a significantly higher kapas yield (21.65 q ha^{-1}), followed by F_2 (20.16 q ha^{-1}), and was superior to the remaining treatments. The interaction effect of irrigation level I_1 combined with nutrient treatment F_3 (I_1F_3) resulted in the highest kapas yield among all treatment combinations. The significant increase in kapas yield under these treatments was mainly attributed to improvements in yield-contributing characters, particularly the increased number of sympodial branches and bolls per plant (Tables 1 and 2).

Water use efficiency (WUE) was significantly influenced by integrated nutrient management practices (Table 2). Among the treatments, F_3 recorded the highest WUE (3.69 kg ha^{-1} mm^{-1}), followed by F_2 (3.43 kg ha^{-1} mm^{-1}). These findings are in close agreement with the results reported by Mussaddak and Sami (2010) [15].

Economic analysis revealed that irrigation level I_1 (0.8 IW/CPE ratio) resulted in significantly higher net returns (₹55,945.08 ha^{-1}) and benefit- cost (B:C) ratio (2.48) compared to the other irrigation regimes. Among nutrient management treatments, F_3 recorded the highest net returns (₹66,153.47 ha^{-1}) and B:C ratio (2.61), which were significantly superior to the remaining treatments. The interaction treatment I_1F_3 was identified as the most economical and sustainable option for Bt cotton production. The higher net monetary returns and B:C ratio under this treatment may be attributed to the synergistic effects of combined application of chemical fertilizers with organic amendments, leading to enhanced productivity and efficient resource utilization. Similar trends were reported by Santhosh *et al*. (2014) [22], Channagouda and Babalad (2015) [9], and Singh *et al*. (2015) [23].

Effect of *in-situ* green manuring, irrigation regimes and micronutrients on soil available nutrient status of cotton in a Vertisol of Malaprabha Command Area

The pooled soil analysis data for two years presented in Table 3 revealed non-significant differences in soil pH and electrical conductivity across irrigation and nutrient management treatments. However, significant variations were observed in soil organic carbon content. Among the irrigation regimes, I_1 recorded a significantly higher organic carbon content (9.83 g kg^{-1}), while among the nutrient management treatments, F_3 recorded the highest organic carbon content (10.05 g kg^{-1}).

The data presented in Table 3 further indicated that, among irrigation levels, I_2 (0.6 IW/CPE ratio) resulted in significantly higher availability of soil nutrients, including available nitrogen (248.80 kg ha^{-1}), available phosphorus (P_2O_5; 32.05 kg ha^{-1}), available potassium (K_2O; 709.36 kg ha^{-1}), iron (5.58 mg kg^{-1}), zinc (1.27 mg kg^{-1}), and boron (0.38 mg kg^{-1}). With respect to nutrient management practices, treatment F_5 recorded significantly higher levels of available nitrogen (255.16 kg ha^{-1}), available P_2O_5 (35.47 kg ha^{-1}), available K_2O (732.39 kg ha^{-1}), iron (5.88 mg kg^{-1}), zinc (1.35 mg kg^{-1}), and boron (0.40 mg kg^{-1}).

The enhanced availability of N, P, and K under integrated nutrient management treatments, particularly those involving in-situ green manuring with sunhemp, may be attributed to the direct addition of nutrients through organic inputs and increased microbial activity, which facilitates mineralization of organically bound nutrients into plant-available forms, especially nitrogen. These findings corroborate the results reported by Thimmareddy *et al.* (2013) [24]. Furthermore, the availability of micronutrients such as zinc, iron, and boron varied significantly among treatments, likely due to differences in organic matter content and nutrient interactions, as also reported by Salem and El-Gizawy (2012) [21].

Table1: Effect of *in-situ* green manuring, irrigation regimes and micronutrients on growth parameters of *Bt* cotton (Pooled data 2016-17 to 2017-18)

Treatments	Plant Height (cm)	No. Of monopodials branches plant^{-1}	No. Of Sympodials branches plant^{-1}
Main-Irrigation levels			
I_1 0.8 IW/CPE ratio	162.71	1.63	34.10
I_2 0.6 IW/CPE ratio	160.43	1.52	32.26
I_3 Critical stages	157.38	1.48	31.32
S.Em±	4.62	0.13	0.34
CD (0.05)	18.12	NS	1.37
Sub- Nutrient levels			
F_1 : 100% RDF + FYM @ 10 t/ha	159.12	1.69	33.87
F_2 : 100% RDF + FYM @ 10 t/ha + one row of sunhemp in between two rows of Bt- Cotton	163.97	1.66	33.85
F_3 : 100% RDF + FYM @ 10 t/ha + one row of sunhemp in between two rows of Bt-cotton + $ZnSO_4.7H_2O$@ 25 kg/ha + $FeSO_4.5H_2O$@ 25 kg/ha + Borax @ 5 kg/ha	164.64	1.61	35.45
F_4 : 75% RDF + FYM @ 10 t/ha + Rhizobium (2g/kg seed) + one row of sunhemp in between two rows of Bt-cotton + $ZnSO_4.7H_2O$@ 25 kg/ha + $FeSO_4.5H_2O$@ 25kg/ha + Borax @ 5kg/ha+ maize stalk 10t/ha	159.70	1.41	31.61
F_5 : 50% RDF + FYM @ 10 t/ha + Rhizobium (2g/kg seed) + one row of sunhemp in between two rows of Bt-cotton + $ZnSO_4.7H_2O$@ 25 kg/ha + $FeSO_4.5H_2O$@ 25 kg/ha + Borax @ 5 kg/ha+ maize stalks @ 10t/ha	153.47	1.43	28.53
S.Em±	2.60	0.06	0.86
CD (0.05)	7.60	NS	2.51
Interactions (Irrigation X Nutrient levels)			
I_1F_1	161.43	1.79	35.96
I_1F_2	171.36	1.80	33.77
I_1F_3	164.72	1.88	37.34
I_1F_4	159.59	1.50	33.24
I_1F_5	156.46	1.47	30.21
I_2F_1	163.87	1.72	32.32
I_2F_2	159.75	1.52	34.25
I_2F_3	164.30	1.48	35.24
I_2F_4	160.38	1.46	31.49
I_2F_5	153.85	1.43	28.03
I_3F_1	152.04	1.57	31.84
I_3F_2	160.79	1.67	33.53
I_3F_3	164.91	1.48	33.78
I_3F_4	159.10	1.28	30.10
I_3F_5	150.08	1.40	27.36
S.Em±	6.13	0.16	1.37
CD (0.05)	17.90	NS	4.02

Table 2: Effect of *in-situ* green manuring, irrigation regimes and micronutrients on yield, WUE and economics of cotton (pooled 2014-17)

Treatments	No. Of Bolls plant^{-1}	Cotton Kapas Yield (q ha^{-1})	Water use efficiency (kg ha^{-1}.mm)	Net returns (Rs ha^{-1})	B.C Ratio
Main-Irrigation levels					
I_1 0.8 IW/CPE ratio	36.99	19.01	3.24	55945.08	2.48
I_2 0.6 IW/CPE ratio	36.55	17.62	3.18	49121.60	2.29
I_3 Critical stages	34.35	16.17	3.36	43762.12	2.25
S.Em±	0.50	0.16	0.07	909.28	0.03
CD (0.05)	1.98	0.55	NS	3146.51	0.10
Sub-Nutrient levels					
F_1	36.05	17.68	3.27	51216.19	2.48
F_2	38.82	18.77	3.48	53696.75	2.38
F_3	41.24	20.23	3.75	59904.70	2.48
F_4	34.44	16.16	3.00	44080.16	2.25
F_5	29.25	15.17	2.81	39150.21	2.11
S.Em±	0.69	0.35	0.08	1448.11	0.04
CD (0.05)	2.03	0.99	0.24	4139.05	0.12
Interactions (Irrigation X Nutrient levels)					
I_1F_1	37.06	18.93	3.22	56198.81	2.55
I_1F_2	39.87	20.16	3.43	60090.92	2.53

I_1F_3	42.97	21.65	3.69	66153.47	2.61
I_1F_4	34.41	17.63	3.00	50004.39	2.34
I_1F_5	30.63	16.69	2.84	47277.83	2.38
I_2F_1	36.02	18.10	3.27	53061.80	2.51
I_2F_2	39.49	19.07	3.45	54828.97	2.39
I_2F_3	41.66	20.31	3.67	60324.38	2.50
I_2F_4	35.35	15.85	2.87	43058.53	2.25
I_2F_5	30.22	14.77	2.67	34334.31	1.80
I_3F_1	35.08	16.00	3.32	44387.95	2.37
I_3F_2	37.10	17.07	3.55	46170.36	2.21
I_3F_3	39.11	18.72	3.89	53236.24	2.34
I_3F_4	33.56	15.00	3.11	39177.56	2.16
I_3F_5	26.90	14.05	2.91	35838.48	2.14
S.Em±	1.19	0.70	0.17	2896.23	0.08
CD (0.05)	3.48	NS	NS	NS	0.24

Table 3: Effect of *in-situ* green manuring, irrigation regimes and micronutrients on soil fertility status of *Bt* cotton (pooled 2016-2017)

Treatments	pH	EC (dSm^{-1})	Organic C ($g\ kg^{-1}$)	Available N ($Kg\ ha^{-1}$)	Available P_2O_5 ($Kg\ ha^{-1}$)	Available K_2O ($Kg\ ha^{-1}$)	Iron	Zinc	Boron
							($mg\ Kg^{-1}$)		
Main-Irrigation levels									
I_1 0.8 IW/CPE ratio	8.14	0.30	9.83	243.72	28.43	669.24	5.37	1.15	0.35
I_2 0.6 IW/CPE ratio	8.17	0.32	9.68	248.80	32.05	709.36	5.58	1.27	0.38
I_3 Critical stages	8.22	0.33	9.48	241.05	31.85	679.84	5.39	1.26	0.34
S.Em±	0.052	0.005	0.04	1.56	0.18	3.16	0.032	0.032	0.007
CD (0.05)	NS	NS	0.17	6.14	0.72	12.42	0.127	0.127	0.026
Sub-Nutrient levels									
F_1	8.30	0.33	9.18	244.45	30.83	693.49	5.20	1.15	0.33
F_2	8.23	0.31	9.53	239.52	28.71	656.33	4.85	1.09	0.32
F_3	8.17	0.34	9.63	233.66	25.79	634.05	5.59	1.23	0.37
F_4	8.10	0.31	9.91	249.83	33.07	714.46	5.71	1.31	0.38
F_5	8.08	0.30	10.05	255.16	35.47	732.39	5.88	1.35	0.40
S.Em±	0.05	0.01	0.10	3.82	0.30	3.46	0.06	0.06	0.01
CD (0.05)	NS	NS	0.29	11.14	0.89	10.49	0.19	0.19	0.03
Interactions (Irrigation X Nutrient levels)									
I_1F_1	8.33	0.31	9.17	244.16	28.59	670.35	5.14	1.05	0.31
I_1F_2	8.27	0.30	9.65	238.33	25.41	643.48	4.73	0.94	0.30
I_1F_3	8.16	0.31	9.85	229.16	23.60	622.33	5.51	1.16	0.36
I_1F_4	8.01	0.30	10.11	250.26	31.21	697.62	5.58	1.28	0.38
I_1F_5	7.92	0.30	10.34	256.71	33.34	712.42	5.87	1.31	0.40
I_2F_1	8.31	0.34	9.21	249.25	31.69	710.05	5.29	1.20	0.34
I_2F_2	8.19	0.32	9.61	244.62	30.20	673.67	5.03	1.14	0.35
I_2F_3	8.11	0.35	9.64	242.18	28.40	652.73	5.77	1.29	0.40
I_2F_4	8.10	0.31	9.94	252.24	33.80	740.22	5.81	1.33	0.41
I_2F_5	8.13	0.30	10.00	255.70	36.50	770.13	5.99	1.39	0.42
I_3F_1	8.23	0.34	9.16	239.95	32.22	700.08	5.16	1.19	0.32
I_3F_2	8.23	0.32	9.35	235.61	30.52	651.85	4.79	1.18	0.29
I_3F_3	8.24	0.35	9.39	229.66	25.71	627.08	5.50	1.25	0.35
I_3F_4	8.20	0.31	9.67	246.98	34.21	705.55	5.74	1.33	0.36
I_3F_5	8.18	0.31	9.82	253.08	36.57	714.63	5.78	1.36	0.37
S.Em±	0.06	0.01	0.17	6.61	0.53	6.00	0.11	0.03	0.02
CD (0.05)	NS	NS	0.51	NS	1.54	17.47	NS	0.08	NS

Conclusion

The field experiment conducted at the Irrigation Water Management Research Centre, Belavatagi, during 2016- 17 to 2017- 18 evaluated the effects of in-situ green manuring, irrigation regimes, and micronutrient management on sustaining Bt cotton yield and soil available nutrient status. The results indicated that irrigation scheduling at 0.8 IW/CPE ratio, combined with the application of 100% recommended dose of fertilizers along with FYM at 10 t ha^{-1}, one row of sunhemp grown as an intercrop between two rows of Bt cotton, and soil application of micronutrients ($ZnSO_4$ at 25 kg ha^{-1}, $FeSO_4$ at 25 kg ha^{-1}, and borax at 5 kg ha^{-1}; treatment F_3), proved to be the most effective nutrient management strategy. This integrated approach sustained Bt cotton yield, improved economic returns, and maintained soil fertility, thereby offering a viable and sustainable production strategy for Bt cotton under Vertisol conditions.

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