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Journal homepage: <http://www.plantarchives.org>

DOI Url : <https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.1.194>

INFLUENCE OF INTEGRATED NUTRIENT MANAGEMENT ON GROWTH, YIELD AND ECONOMIC RETURNS OF *BT* COTTON (*GOSSYPIUM HIRSUTUM* L.) UNDER *VERTISOL* CONDITIONS OF SOUTH GUJARAT

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(Date of Receiving : 18-01-2026; Date of Revision : 08-03-2026; Date of Acceptance : 27-03-2026)

ABSTRACT

A field experiment was conducted during *Kharif* 2024–25 at Main Cotton Research Station, Navsari Agricultural University, Surat, Gujarat to evaluate the Influence of Integrated Nutrient Management on Growth, Yield and Economic Returns of *Bt* Cotton (*Gossypium hirsutum* L.) under *Vertisol* Conditions of South Gujarat. The soil of experimental field was clayey in texture, low in organic carbon content (0.44%) and 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) with pH 7.78, EC 0.42 dS m⁻¹ and BD 1.34 Mg m⁻³. The experiment consisted of ten treatments *i.e.*, T₁ (100% RDF), T₂ (100% RDN through FYM), T₃ (100% RDN through Biocompost), T₄ (75% RDF + 25% RDN through FYM), T₅ (75% RDF + 25% RDN through Biocompost), T₆ (75% RDF + 25% RDN through FYM + Green manuring with sunhemp), T₇ (75% RDF + 25% RDN through Biocompost + Green manuring with sunhemp), T₈ (50% RDF + 25% RDN through FYM + 25% RDN through Neemcake + Green manuring with sunhemp), T₉ (50% RDF + 25% RDN through Biocompost + 25% RDN through Neemcake + Green manuring with sunhemp), T₁₀ (Absolute Control) and was laid out in Randomized Block Design with three replications. Results revealed that Application of 75% RDF combined with 25% RDN through biocompost along with green manuring using sunhemp resulted in significantly higher plant height (148.53 cm) which was statistically at par with treatment T₆, T₅, T₄ and T₁. Treatment T₇ significantly increased number of bolls per plant (42.30) and seed cotton yield per plant (136.73 g), and remained at par with T₆ and T₅. Boll weight was not significantly influenced by different treatments. Higher seed cotton yield (2388 kg ha⁻¹) and stalk yield (5944 kg ha⁻¹) were recorded under T₇, which was statistically at par with treatment T₆, T₅ and T₄ (seed cotton yield) and T₆, T₅, T₄ and T₁ (stalk yield). Treatment T₇ recorded the highest gross return (Rs. 2,02,876 ha⁻¹) and net return (Rs. 1,50,244 ha⁻¹), while the highest Benefit: Cost ratio (4.00) was observed in T₅, followed by T₁ and T₇. Absolute control recorded the lowest growth, yield and economic returns of *Bt* Cotton. The findings indicate that partial substitution of inorganic fertilizers with organic sources along with green manuring enhances productivity and profitability of *Bt* cotton under South Gujarat conditions.

Keywords : *Bt* cotton, Organic sources, Integrated Nutrient Management, Seed Cotton Yield, Economic Returns.

Introduction

Cotton (*Gossypium hirsutum* L.) is one of the most important fibre and cash crops grown in tropical and sub-tropical regions of the world. In India, it plays

a vital role in the agricultural economy by supporting millions of farmers and supplying raw material to the textile industry. Among cultivated species, *G. hirsutum* accounts for nearly 88 per cent of hybrid cotton

production due to its high yield potential and wide adaptability. *Bt* cotton hybrids, developed through incorporation of genes from *Bacillus thuringiensis*, provide resistance against bollworms and have significantly improved yield and farm profitability in India (Kathage and Qaim, 2012). India ranks second in global cotton production after China. During 2024-25, cotton production in India is estimated at 299.26 lakh bales (170 kg each) from 113.60 lakh hectares, with an average productivity of 448 kg lint ha⁻¹ (Anon., 2024-25). Gujarat is a leading cotton-producing state, contributing more than 31 per cent of national production and cultivating cotton on over 30 lakh hectares.

Enhancement of cotton production and productivity largely depends on maintaining and improving soil fertility. Continuous nutrient removal without adequate replenishment has led to soil degradation and declining yields, particularly under rainfed conditions. Sole dependence on chemical fertilizers is becoming increasingly difficult due to escalating input costs and environmental concerns. Imbalanced fertilization and lack of crop residue recycling have adversely affected soil health (Campbell *et al.*, 2001; Roldan *et al.*, 2003; Sharma *et al.*, 2008). Organic manures improve soil physico-chemical and biological properties by enhancing aggregation, porosity, moisture retention and nutrient buffering capacity (Tisdale *et al.*, 1985). Integrated Nutrient Management (INM), which combines inorganic fertilizers with organic sources such as farmyard manure, compost, green manures and crop residues, has emerged as a sustainable approach to improve crop productivity and soil health. Organic amendments increase cation exchange capacity and microbial activity, while inorganic fertilizers ensure immediate nutrient availability. The synergistic use of both sources enhances nutrient use efficiency and maintains balanced nutrient supply throughout the crop growth period (Smith, 1992; Chandel *et al.*, 2017). Economic viability is an important factor influencing the adoption of nutrient management practices by farmers. Increasing fertilizer prices and higher cultivation costs require nutrient management strategies that not only enhance crop productivity but also improve net returns and benefit: cost ratio under field conditions. Studies have shown that *Bt* cotton adoption significantly increased farm profits through higher yields and reduced pest damage (Kathage and Qaim, 2012).

Therefore, the present investigation entitled “Influence of Integrated Nutrient Management on Growth, Yield and Economic Returns of *Bt* Cotton

(*Gossypium hirsutum* L.) under *Vertisol* Conditions of South Gujarat” was undertaken to evaluate the effect of different INM practices on growth, yield attributes and economic returns of *Bt* cotton under South Gujarat conditions.

Materials and Methods

A field experiment entitled “Influence of Integrated Nutrient Management on Growth, Yield and Economic Returns of *Bt* Cotton (*Gossypium hirsutum* L.) under *Vertisol* Conditions of South Gujarat” was conducted at the Main Cotton Research Station, Navsari Agricultural University, Surat, Gujarat during *Kharif* season of 2024–25. The 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 experimental soil was *Vertisol* (*Typic Haplichromerts*) belonging to the Surat soil series, commonly known as deep black soil. The soil was clayey in texture, slightly alkaline in reaction (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 micronutrients such as Fe, Mn, Zn and Cu were 9.33, 4.95, 1.32 and 2.16 mg kg⁻¹, respectively. Soil samples (0-15 cm depth) were collected before sowing and analyzed using standard procedures. Soil pH was determined by glass electrode method, electrical conductivity by conductivity meter, organic carbon by Walkley and Black method, available nitrogen by alkaline KMnO₄ method, available phosphorus by Olsen's method, available potassium by flame photometer and micronutrients by DTPA extraction method. The experiment was laid out in randomized block design with ten treatments and three replications. The treatments consisted of different combinations of chemical fertilizers and organic nutrient sources *viz.*, T₁ - 100% recommended dose of fertilizers (RDF); T₂ - 100% recommended dose of nitrogen (RDN) through farmyard manure (FYM); T₃ - 100% RDN through biocompost; T₄ - 75% RDF + 25% RDN through FYM; T₅ - 75% RDF + 25% RDN through biocompost; T₆ - 75% RDF + 25% RDN through FYM along with green manuring using sunhemp; T₇ - 75% RDF + 25% RDN through biocompost along with green manuring using sunhemp; T₈ - 50% RDF + 25% RDN through FYM + 25% RDN through neem cake along with green manuring using sunhemp; T₉ - 50% RDF + 25% RDN through biocompost + 25% RDN through neem cake along with green manuring using sunhemp; and T₁₀ - absolute control. The recommended dose of fertilizer

was 240-40-00 kg N, P₂O₅, K₂O ha⁻¹ supplied through urea and SSP as per treatment. No potassium was applied due to high initial soil K status. Organic sources such as FYM, biocompost, neem cake and sunhemp were analyzed for moisture and nutrient content as describe in Table 1 and applied on nitrogen equivalent basis as basal application. Sunhemp (*Crotalaria juncea*) was incorporated at 50% flowering stage. Cotton variety G. Cot. Hy. -10 (BG-II) was sown at a seed rate of 2.5 kg ha⁻¹ on 1st July 2024 using line sowing method at spacing of 120 × 45 cm. The gross plot size was 6.00 × 6.30 m and net plot size was 3.60 × 5.40 m. Two seeds were dibbled per hill at a depth of 5-6 cm under adequate soil moisture conditions. Standard agronomic practices were followed uniformly for all treatments. Hand weeding was carried out four times during the crop growth period. All growth and yield observations were recorded at harvest stage. Plant height was measured from ground level to the growing tip of the main stem from five randomly tagged plants in each net plot and expressed in centimeter. Number of bolls per plant was counted from the same tagged plants and averaged. Five fully matured open bolls were randomly selected from each net plot to record boll weight (g). Seed cotton yield from tagged plants was recorded and averaged. Total seed cotton yield from each net plot was recorded at each picking, summed and converted into kilogram per hectare. After final picking, plants from net plot were uprooted, sun-dried for 20 days and stalk yield was recorded and converted into kg ha⁻¹. The economic evaluation of different treatments was carried out based on prevailing market prices during 2024-25. The cost of cultivation for each treatment was calculated considering the cost of all inputs and field operations from land preparation to harvest. Gross returns were computed based on seed cotton and stalk yield at prevailing market prices. Net returns were obtained by deducting total cost of cultivation from gross returns. The benefit-cost (B:C) ratio was calculated by dividing gross returns by total cost of cultivation, and the treatment with higher net return and B:C ratio was considered economically superior. The experimental data were statistically analyzed using analysis of variance (ANOVA) appropriate to Randomized Block Design as described by Panse and Sukhatme (1985). The significance of treatment differences was tested by 'F' test at 5 per cent level of significance. Critical Difference (CD) at 5% level was calculated for comparison of treatment means.

Table 1: Chemical compositions of different organic sources

Sr. 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 ⁻¹)	1025	2164	1422	394
6.	Mn (mg kg ⁻¹)	132	216	95	168
7.	Zn (mg kg ⁻¹)	32	58	54	53
8.	Cu (mg kg ⁻¹)	15	34	28	21

Results and Discussion

Effect of different treatments on plant height, number of bolls per plant, boll weight and seed cotton yield per plant of *Bt* cotton

Plant height

The plant height of *Bt* cotton as influenced by different organic nutrient management treatments is presented in Table 2. The data showed that significantly higher plant height (148.53 cm) was recorded with treatment T₇ (75% RDF + 25% RDN through Biocompost + Green manuring with sunhemp) which was statistically at par with treatment T₆, T₅, T₄ and T₁ with corresponding value of 142.86 cm, 135.36 cm, 131.73 cm and 127.50 cm, respectively. However, significantly lower plant height (92.06 cm) was recorded with treatment T₁₀ (Absolute Control).

The increase in plant height under integrated nutrient management treatments might be attributed to balanced and continuous nutrient supply throughout the crop growth period. Combined application of organic and inorganic sources improved soil physical properties, moisture retention and microbial activity, thereby enhancing root development and nutrient uptake. The gradual nutrient release from organic sources along with readily available nutrients from inorganic fertilizers ensured sustained availability during critical growth stages. Adequate nitrogen supplies enhanced chlorophyll synthesis, photosynthetic efficiency and cell elongation, resulting in increased vegetative growth and plant height. These findings are in accordance with the results reported by Dadgale *et al.* (2014); Mahadevappa *et al.* (2018); Iqbal *et al.* (2020); Singh *et al.* (2020) and Subramanian *et al.* (2020).

Number of bolls per plant

The number of bolls per plant of *Bt* cotton as influenced by different organic nutrient management

treatments is presented in Table 2. Significantly higher number of bolls per plant (42.30) was recorded in application of 75% RDF + 25% RDN through Biocompost + Green manuring with sunhemp (T₇) which was statistically at par with treatment T₆ and T₅ with value of 39.90 and 36.86, respectively. However, the result further showed that significantly lower value (19.66) was recorded with treatment T₁₀ (Absolute Control).

The increase in boll number under integrated nutrient management treatments might be attributed to balanced and sustained nutrient availability throughout the crop growth period. Combined application of organic and inorganic sources improved soil fertility, microbial activity and nutrient mineralization, resulting in better flowering and boll retention. Adequate nitrogen and phosphorus supply enhanced reproductive development and reduced boll shedding, thereby increasing the number of bolls per plant. The gradual release of nutrients from organic sources along with readily available nutrients from mineral fertilizers ensured continuous nutrient supply during critical growth stages. These findings are in agreement with the results reported by Gabhane *et al.* (2014), Pandiselvi and Manoharan (2015), Vora *et al.* (2015), Channagouda *et al.* (2015), Iqbal *et al.* (2020) and Subramanian *et al.* (2020).

Boll weight

The boll weight of *Bt* cotton as influenced by different organic nutrient management treatments is presented in Table 2. According to data in table revealed that boll weight of *Bt* cotton at harvest was non significantly influenced by different treatments which indicates that all the treatments did not find any influence on boll weight, but show positive response towards applied organic sources in combination with recommended doses of nutrients. Higher (3.60 g) boll weight found in treatment T₇ while lower (3.00 g) boll weight was found in treatment T₁₀. Application of organic sources in combination with recommended doses of nutrients did affect the boll weight in *Bt* cotton. This combination enhanced timely nutrient availability during crop growth stages, supporting better crop performance as reported by Pandiselvi and Manoharan (2015). Similar results were reported Dadgale *et al.* (2014); Gabhane *et al.* (2014); Channagouda *et al.* (2015); Singh *et al.* (2020) and Subramanian *et al.* (2020) in *Bt* cotton.

Seed Cotton Yield per Plant

The data pertaining to seed cotton yield per plant recorded at harvest are presented in Table 2. The result regarding seed cotton yield per plant at harvest

significantly differs with different treatments. Significantly higher seed cotton yield per plant (136.73 g) was recorded in application of 75% RDF + 25% RDN through Biocompost + Green manuring with sunhemp (T₇) which was statistically at par with treatment T₆ and T₅ with value of 132.36 g and 128.46 g, respectively. However, the result further showed that significantly lower value (57.86 g) was recorded with treatment T₁₀ (Absolute Control).

Significantly higher seed cotton yield per plant was recorded under the integrated application of green manuring with sunhemp along with biocompost and reduced levels of inorganic fertilizers. The incorporation of sunhemp, a fast-growing leguminous crop, might have contributed to increased organic matter content and biological nitrogen fixation, thereby improving soil fertility and microbial activity. The combined use of organic and inorganic nutrient sources ensured balanced and sustained nutrient availability throughout the crop growth period, particularly during boll development and seed formation stages. Improved nutrient supply enhanced physiological efficiency and photosynthate partitioning towards reproductive structures, resulting in higher yield per plant. These findings are in agreement with the results reported by Kamble *et al.* (2009) and Channagouda *et al.* (2015) in cotton.

Table 2: Effect of different treatments on plant height, number of bolls per plant, boll weight and seed cotton yield per plant of *Bt* cotton

Treatments	Plant height (cm)	Bolls per plant	Boll weight (g)	Seed cotton yield per plant (g)
T ₁	127.50	33.66	3.43	114.06
T ₂	107.93	25.30	3.23	79.93
T ₃	112.73	28.10	3.26	84.66
T ₄	131.73	34.46	3.46	120.26
T ₅	135.36	36.86	3.50	128.46
T ₆	142.86	39.90	3.53	132.36
T ₇	148.53	42.30	3.60	136.73
T ₈	113.83	28.33	3.36	93.00
T ₉	117.63	30.60	3.40	102.70
T ₁₀	92.06	19.66	3.00	57.86
SEM ±	7.52	1.84	0.17	5.01
CD at 5%	22.53	5.51	NS	15.01
CV (%)	10.59	9.98	9.11	8.27

Effect of different treatment on seed cotton and stalk yield of *Bt* cotton

Seed cotton yield

The seed cotton yield (kg ha⁻¹) was calculated based on seed yield obtained from the net plot (kg

plot⁻¹) and was subjected to statistical analysis. The result obtained have been presented in Table 3. An appraisal of the data showed that seed cotton yield was significantly influenced due to the different treatments. The application of 75% RDF + 25% RDN through Biocompost + Green manuring with sunhemp (T₇) recorded significantly higher seed cotton yield (2388 kg ha⁻¹) which was statistically at par with treatment T₆, T₅ and T₄ with corresponding value of 2296, 2259 and 2198 kg ha⁻¹, respectively. The results further showed that significantly lower seed yield of *Bt* cotton (1081 kg ha⁻¹) was recorded with treatment T₁₀ (Absolute Control).

The application of organic sources such as FYM and compost improved soil physical properties and significantly enhanced seed cotton yield. Their decomposition accelerated nutrient mineralization, increasing nitrogen availability, while organic acids improved phosphorus solubility and potassium availability (Jan *et al.* 2020). Mineral fertilizers supplied readily available macronutrients during early crop growth, whereas organically bound nutrients in FYM were gradually released, reducing nutrient losses through volatilization and leaching. The combined application of mineral fertilizers and FYM resulted in optimum seed cotton yield due to immediate nutrient availability from inorganic sources complemented by sustained nutrient release through mineralization of organic materials. In-situ incorporation of sunhemp as green manure further enriched the soil with organic matter and biologically fixed nitrogen, improving microbial activity and nutrient availability during mid-season. Improved rhizospheric conditions enhanced boll development and yield. These findings are in agreement with earlier reports in cotton by Raskar (2004), Bhoite and Thombre (2006), Raut *et al.* (2006), Srinivasulu and Hema (2007), Kamble *et al.* (2009), Sonune *et al.* (2012), Gabhane *et al.* (2014), Channagouda *et al.* (2015), Vora *et al.* (2015), Subramanian *et al.* (2020), Iqbal *et al.* (2020) and Chen *et al.* (2023), who also observed improved yield under integrated nutrient management practices.

Stalk yield

The stalk yield of net plot was noted at the time of harvest which was converted to per hectare. The numerical data regarding the stalk yield have been presented in Table 3. The result showed that stalk yield was significantly influenced by the different treatments. The data showed that significantly higher stalk yield (5944 kg ha⁻¹) was recorded with treatment T₇ (75% RDF + 25% RDN through Biocompost + Green manuring with sunhemp) which was statistically at par with treatment T₆, T₅ and T₁ with corresponding

value of 5626, 5470, 5318 and 5237 kg ha⁻¹, respectively. Significantly lower stalk yield (2466 kg ha⁻¹) was recorded under treatment T₁₀ (Absolute Control).

The increase in stalk yield under integrated nutrient management treatments might be attributed to enhanced photosynthetic activity and improved carbohydrate synthesis, resulting in greater dry matter accumulation, plant height and branching. Inorganic fertilizers ensured early availability of essential macronutrients, particularly nitrogen and phosphorus, during critical stages of vegetative growth. Application of FYM and biocompost improved soil physical properties, moisture retention and root proliferation, thereby enhancing nutrient uptake. In-situ incorporation of sunhemp as green manure further enriched the soil with organic matter and biologically fixed nitrogen upon decomposition. Although nutrients from green manure are released gradually, its positive effects on soil structure, aeration and microbial activity created a favourable rhizospheric environment throughout the crop growth period. These favourable soil and plant responses collectively resulted in higher stalk productivity. Similar findings were reported by Sonune *et al.* (2012), Channagouda *et al.* (2015) and Singh *et al.* (2020).

Table 3: Effect of different treatment on seed cotton and stalk yield of *Bt* cotton

Treatments	Seed cotton yield (kg ha ⁻¹)	Stalk yield (kg ha ⁻¹)
T ₁	2080	5237
T ₂	1422	3805
T ₃	1550	4015
T ₄	2198	5318
T ₅	2259	5470
T ₆	2296	5626
T ₇	2388	5944
T ₈	1763	4535
T ₉	1894	4817
T ₁₀	1081	2466
SEm ±	84.11	221.40
CD at 5%	251.84	662.91
CV (%)	7.69	8.11

Effect of different treatment on economics of *Bt* cotton

Economic evaluation of different nutrient management treatments is essential for assessing their practical feasibility and recommending suitable agronomic practices. Therefore, cost of cultivation, gross return, net return and benefit: cost (B:C) ratio were computed based on prevailing market prices of seed cotton and stalk, and are presented in Table 4. The data indicated that treatment T₇ (75% RDF + 25%

RDN through biocompost + green manuring with sunhemp) recorded the highest gross return (Rs. 2,02,876 ha⁻¹) and net return (Rs. 1,50,244 ha⁻¹). The lowest gross return (Rs. 90,939 ha⁻¹) was observed under T₁₀ (absolute control), whereas the lowest net return was recorded under T₂ (100% RDN through FYM). Maximum B:C ratio (4.00) was obtained with T₅, followed by T₁ (3.96) and T₇ (3.85), while the lowest B:C ratio (1.58) was recorded under T₂. Higher economic returns under integrated nutrient management treatments were mainly due to increased seed cotton and stalk yield with efficient utilization of applied inputs. These findings are in similar with earlier reports by Vora *et al.* (2015), Manjunatha *et al.* (2017) and Rakhonde *et al.* (2022).

Table 4: Effect of different treatment on economics of *Bt* cotton

Treat-ments	Seed cotton yield (kg ha ⁻¹)	Stalk yield (kg ha ⁻¹)	Cost of cultivation (Rs. ha ⁻¹)	Gross returns (Rs. ha ⁻¹)	Net returns (Rs. ha ⁻¹)	Benefit: Cost ratio
T ₁	2080	5237	44672	176948	132276	3.96
T ₂	1422	3805	77321	121870	44549	1.58
T ₃	1550	4015	57322	132310	73432	2.31
T ₄	2198	5318	52824	186122	133298	3.52
T ₅	2259	5470	47826	191305	143479	4.00
T ₆	2296	5626	57610	194704	137094	3.38
T ₇	2388	5944	52632	202876	150244	3.85
T ₈	1763	4535	89291	150365	61074	1.68
T ₉	1894	4817	84293	161318	77025	1.91
T ₁₀	1081	2466	35643	90939	55296	2.55

Note: Selling Price of cotton seed (Rs. 75 kg⁻¹) and Selling Price of cotton stalk (Rs. 4 kg⁻¹)

Conclusion

The present investigation revealed that integrated nutrient management significantly influenced growth, yield and economic returns of *Bt* Cotton under *Vertisol* Conditions of South Gujarat. Application of 75% RDF combined with 25% RDN through biocompost along with green manuring using sunhemp (T₇) resulted in significantly higher plant height (148.53 cm) which was statistically at par with T₆, T₅, T₄ and T₁. T₇ significantly increased number of bolls per plant (42.30) and seed cotton yield per plant (136.73 g), and remained at par with T₆ and T₅. Boll weight was not significantly influenced by different treatments. Higher seed cotton yield (2388 kg ha⁻¹) and stalk yield (5944 kg ha⁻¹) were recorded under T₇, though statistically comparable with T₆, T₅ and T₄ (seed cotton yield) and T₆, T₅, T₄ and T₁ (stalk yield). T₇ registered the highest gross return (Rs. 2,02,876 ha⁻¹) and net return (Rs. 1,50,244 ha⁻¹), while the highest Benefit: Cost ratio (4.00) was observed in T₅, followed by T₁ and T₇. Absolute control recorded the lowest growth, yield and economic returns of *Bt* Cotton. Overall, partial

substitution of chemical fertilizers with organic sources along with green manuring improved productivity and profitability of *Bt* cotton under South Gujarat conditions.

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