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A study of the economics of different treatments on soybean

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Abstract
Soybean (*Glycine max* L.) is a vital oilseed crop with significant economic and nutritional value. However, optimizing its yield and profitability requires the implementation of effective agronomic practices. This study evaluates the economic feasibility of different soybean treatments by analyzing their impact on grain and straw yield, gross returns, cost of cultivation, net profit, and benefit-cost (B:C) ratio. Eight treatments were compared, including the recommended dose of fertilizers (RDF) alone and in combination with various bio-inoculants and micronutrients such as Rhizobium, phosphate-solubilizing bacteria (PSB), ammonium molybdate, zinc sulfate, boron, iron, manganese, and farmyard manure (FYM). The results indicated that the highest net return (₹32,108) and B:C ratio (1:2.98) were obtained with the application of RDF + ammonium molybdate (1g/kg seed) + Rhizobium + PSB (T4), making it the most economically viable treatment. In contrast, the lowest net return (₹11,456) and B:C ratio (1:1.34) were observed in the manganese-supplemented treatment (T7), indicating lower cost-effectiveness. These findings highlight the importance of integrating bio-inoculants and micronutrients to enhance soybean productivity and profitability. The study provides valuable insights for farmers and policymakers in selecting cost-effective agronomic practices for sustainable soybean cultivation.

Keywords: Soybean, Economics, PSB, RDF

Introduction
Soybean (*Glycine max* L.) is a vital oilseed and leguminous crop that plays a crucial role in global agriculture due to its high protein content, oil yield, and nitrogen-fixing ability. It serves as a key raw material in the food, feed, and biofuel industries, making its cultivation an essential component of sustainable farming systems. However, achieving higher productivity and profitability in soybean farming depends on various agronomic practices, including fertilizer application, seed inoculation, and soil amendments. The economic viability of different treatments needs to be assessed to determine the most cost-effective approach for enhancing yield while maintaining sustainability. This study evaluates the economics of different soybean treatments by analyzing parameters such as grain and straw yield, gross return, cost of cultivation, net profit, and benefit-cost (B:C) ratio. Economic analysis is a crucial aspect of agricultural research, as it helps farmers and policymakers make informed decisions regarding input utilization and management strategies. The choice of fertilizers, bio-inoculants, and soil amendments significantly impacts the overall cost of production and profitability. Traditional fertilization methods, including the recommended dose of fertilizers (RDF), are commonly used, but integrating additional treatments like Rhizobium, phosphate-solubilizing bacteria (PSB), and micronutrients such as zinc, boron, iron, and molybdenum can further enhance yield. While these treatments improve soil fertility and plant nutrition, their economic feasibility must be evaluated to ensure that the additional input costs translate into higher profits [1-2].
The study categorizes the treatments into different groups based on the type of nutrient amendments used. The baseline treatment (T1) involves RDF alone, which provides essential macronutrients required for soybean growth. The second treatment (T2) integrates Rhizobium and PSB inoculation, which promote biological nitrogen fixation and phosphorus solubilization, respectively. The third treatment (T3) includes the addition of zinc sulfate ($ZnSO_4$) to address zinc deficiency, which is known to impact soybean growth. The fourth treatment (T4) introduces

ammonium molybdate (AM) along with Rhizobium and PSB, as molybdenum plays a crucial role in nitrogen fixation. Other treatments include boron supplementation (T5), iron supplementation (T6), manganese supplementation (T7), and farmyard manure (FYM) application (T8) [3-4]. the economic performance of each treatment is evaluated based on its ability to enhance yield and profitability. The study employs a comprehensive economic assessment by calculating the total revenue generated from grain and straw yield, the total cost incurred in fertilizers and other cultivation inputs, and the net return derived from each treatment. The benefit-cost ratio (B:C) is used as a key indicator of economic efficiency, where a higher ratio implies greater profitability. Among all treatments, T4 (RDF + ammonium molybdate @ 1g/kg seed + Rhizobium + PSB) exhibited the highest net return of ₹32,108, with a B:C ratio of 1:2.98. This suggests that integrating ammonium molybdate along with biological inoculants significantly enhances profitability. The second-best treatment was T3 (RDF + $ZnSO_4$ + Rhizobium + PSB), which provided a net return of ₹28,500 and a B: C ratio of 1:2.60. Similarly, T8 (RDF + FYM + Rhizobium + PSB) showed promising results, indicating that organic amendments can contribute to economic benefits. On the other hand, T7 (RDF + $MnSO_4$ + Rhizobium + PSB) resulted in the lowest profitability, with a net return of ₹11,456 and a B: C ratio of 1:1.34. This suggests that manganese application did not significantly enhance yield compared to the additional cost incurred. Other treatments, such as boron (T5) and iron (T6) supplementation, also showed moderate profitability but were less effective than T4. These findings highlight the importance of selecting appropriate nutrient amendments based on their cost-effectiveness. Overall, this study provides valuable insights into the economic feasibility of different soybean treatments. The results indicate that a combination of RDF with ammonium molybdate, Rhizobium, and PSB offers the highest profitability, making it a viable option for farmers aiming to maximize returns. Additionally, the study underscores the significance of integrating biological inoculants with chemical fertilizers to enhance nutrient uptake and crop productivity in a cost-effective manner. By adopting scientifically proven treatments with a favorable cost-benefit ratio, soybean farmers can optimize their input use and improve economic sustainability [5]. “

Literature review

Shinde *et al*. (2009) studied the effect of integrated nutrient management (INM) on the yield attributes and quality of soybean. Their findings demonstrated that a combination of organic and inorganic nutrient sources significantly enhanced pod formation, seed weight, and protein content in soybean. The study emphasized that INM improves soil fertility by ensuring a balanced nutrient supply while reducing reliance on chemical fertilizers. Additionally, organic inputs such as farmyard manure and biofertilizers contributed to better root development and increased microbial activity in the soil, leading to improved nutrient uptake and yield sustainability [6].

Tiwari *et al*. (1997) analyzed the influence of manure and fertilizers on soybean physiological growth parameters and yield. Their research revealed that organic manure application significantly improved root length, leaf area, and chlorophyll content, ultimately leading to better photosynthetic efficiency and biomass accumulation. The combination of organic manure and chemical fertilizers resulted in the highest seed yield, suggesting a synergistic effect on soybean productivity. The study reinforced the importance of integrating organic and inorganic fertilization methods for sustainable soybean cultivation and long-term soil fertility maintenance [7].

Thakur *et al*. (2011) investigated the impact of continuous inorganic and organic fertilizer application on soil properties and soybean-wheat cropping system productivity in vertisols. The results indicated that prolonged chemical fertilizer use led to nutrient imbalances and soil degradation, while organic manure incorporation improved soil structure, microbial activity, and moisture retention. The highest yield was observed in treatments integrating both fertilizers and organic amendments, proving that a balanced fertilization approach is key to maintaining soil health and crop productivity in intensive cropping systems [8].

Zaidi *et al*. (2003) explored the interactive effect of rhizotrophic microorganisms on yield and nutrient uptake in chickpea, providing insights applicable to soybean cultivation. Their study highlighted that inoculation with beneficial soil microbes, such as Rhizobium and phosphate-solubilizing bacteria, significantly increased nitrogen fixation, phosphorus availability, and plant biomass. These improvements led to enhanced seed yield and nutrient content in chickpea plants. The research underscored the importance of biofertilizers in legume production systems, demonstrating their potential in reducing chemical fertilizer dependency while ensuring sustainable crop growth [9].

Zarei *et al*. (2012) examined the effects of biofertilizers on grain yield and protein content in two soybean cultivars. Their study found that treatments with nitrogen-fixing and phosphorus-solubilizing bacteria led to a significant increase in yield and protein levels in soybean seeds. The application of biofertilizers improved nutrient availability and uptake efficiency, resulting in better growth performance and seed quality. The findings emphasized the role of microbial inoculants in enhancing soybean productivity, especially under conditions where chemical fertilizers may not be feasible or sustainable in the long term [10].

Research methodology

1. Experimental Design

A field experiment was conducted to evaluate the economic feasibility of different soybean treatments. The study employed a randomized block design (RBD) with multiple treatments (T1 to T8), each replicated across the experimental plots.

2. Treatments

The treatments included combinations of recommended dose of fertilizers (RDF), bio-inoculants (Rhizobium and PSB), and various micronutrient applications, such as:

- T1: RDF (20:60:20:20, N:P_2O_5:K_2O:S kg/ha)
- T2: RDF + Rhizobium + PSB inoculation
- T3: RDF + $ZnSO_4$ 50 kg/ha + Rhizobium + PSB inoculation
- T4: RDF + Ammonium Molybdate (1g/kg seed) + Rhizobium + PSB inoculation
- T5: RDF + Borax 5 kg/ha + Rhizobium + PSB inoculation
- T6: RDF + $FeSO_4$ 10 kg/ha + Rhizobium + PSB inoculation
- T7: RDF + $MnSO_4$ 25 kg/ha + Rhizobium + PSB inoculation
- T8: RDF + Farmyard Manure (FYM) 5 t/ha + Rhizobium + PSB inoculation

3. Data Collection

The following parameters were recorded during the experiment:

- Grain yield (kg/ha)
- Straw yield (kg/ha)
- Gross return (₹/ha) (Calculated based on prevailing market prices of soybean grain and straw)

- Cost of cultivation (₹/ha) (Includes cost of fertilizers, bio-inoculants, labour, land preparation, sowing, irrigation, pest control, harvesting, and post-harvest handling)
- Net profit (₹/ha) (Gross return – Cost of cultivation)
- Benefit-Cost (B:C) ratio (Net profit / Cost of cultivation)

4. Economic Analysis

The economic feasibility of each treatment was analyzed by computing:

- Total revenue generated from grain and straw yield
- Total cost incurred for fertilizers, amendments, and cultivation practices
- Profitability in terms of net return and B:C ratio

5. Statistical Analysis

- The obtained data were analyzed using statistical tools to determine the significance of variations among treatments.
- The best-performing treatment was identified based on highest net return and B:C ratio.

Results and Discussion

The economic analysis of different soybean treatments was carried out by considering the market rates of various production inputs and the returns obtained during the experiment. The profitability of each treatment was assessed based on gross return, net profit, and benefit-cost (B:C) ratio. The results revealed that the highest net return (₹32,108/ha) was obtained in T4 (RDF + Ammonium Molybdate 1g/kg seed + Rhizobium + PSB inoculation), followed by T3 (₹28,500/ha), T8 (₹27,769/ha), and T2 (₹27,763/ha). The lowest net return was observed in T7 (₹11,456/ha), attributed to the high cost of cultivation. Among the treatments, the highest B:C ratio (1:2.98) was recorded in T4, indicating superior economic feasibility. The treatments T2, T3, and T8 also showed promising results, whereas T7 exhibited the lowest B:C ratio (1:1.34), suggesting lower profitability due to high input costs.

Economics

The economics of various treatments was worked out by taking into account the market rates of various production inputs over control and produced during the course of investigation (Table 30 and appendix XIII).

The highest net return (₹32108.00) was obtained in T4 ie. The application of RDF + Ammonium Molybdate (A.M.) @ 1g / kg seed +Rhizobium + PSB (T4) followed by treatments T8 (₹27769.00), T3 (₹ 28500.00), T2 (₹ 27763.00) and with T5 (₹25381.00). The highest B:C ratio 1:2.98 was obtained with application of RDF + Ammonium Molybdate (A.M.) @ 1g / kg seed +Rhizobium + PSB (T4).

Economics of various treatments of soybean

Soybean (*Glycine max*) is an economically significant crop due to its high protein and oil content, making it a valuable commodity in food, feed, and industrial applications. Enhancing soybean productivity through optimized nutrient management and biofertilizer application is crucial for maximizing yield and profitability.

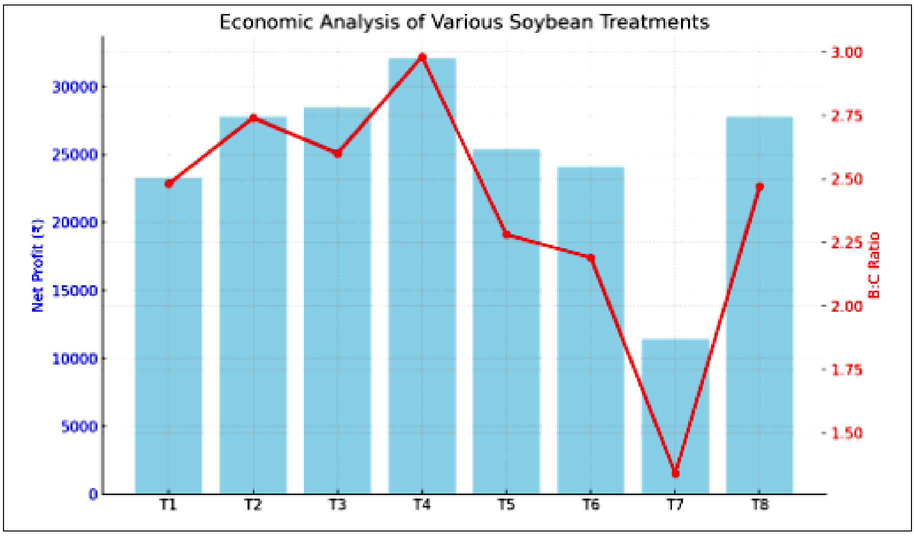
Economic analysis of different treatments helps in determining the most cost-effective approach to soybean cultivation by evaluating gross return, cost of cultivation, net profit, and benefit-cost (B:C) ratio. This study assesses the financial viability of different nutrient and biofertilizer combinations, including recommended dose of fertilizers (RDF), micronutrient supplements ($ZnSO_4$, $FeSO_4$, $MnSO_4$, Borax, and Ammonium Molybdate), biofertilizers (Rhizobium and PSB), and organic amendments (FYM).

By analyzing the economics of various treatments, farmers and researchers can identify the most profitable and sustainable strategies for soybean production. The study aims to:

- Compare the yield and economic returns of different fertilization and inoculation treatments.
- Identify the most cost-effective treatment based on net profit and B:C ratio.
- Provide insights into the role of biofertilizers and micronutrient supplementation in improving soybean yield and farm profitability.

Table 1: Economics of various treatments of soybean

	Treatments	Grain yield (kg/ha)	Straw yield (kg/ha)	Gross return (₹)	Cost of cultivation (₹)	Net profit (₹)	B:C ratio
T1	RDF(20:60:20:20,N:P2O5:k20:S)kg-1	1010.00	1201.00	38953.00	15659.00	23294.00	1:2.48
T2	RDF+Rhizobium+PSB inoculation	1132.00	1336.00	43628.00	15865.00	27763.00	1:2.74
T3	RDF + ZnSO4 50 kg/ha + Rhizobium +PSB inoculation	1200.00	1410.00	46230.00	17730.00	28500.00	1:2.60
T4	RDF+Ammo.Molyb.1g/kgseed+ Rhizobium + PSB inoculation	1255.00	1456.00	48293.00	16185.00	32108.00	1:2.98
T5	RDF+Borax5kg/ha+Rhizobium+PSB inoculation”	1170.00	1392.00	45126.00	19745.40	25381.00	1:2.28
T6	RDF +FeSO4 10 kg/ha +Rhizobium +PSB inoculation	1149.00	1356.00	44283.00	20165.00	24118.00	1:2.19
T7	RDF+ MnSO4 25 kg/ha + Rhizobium +PSB inoculation	1160.00	1357.00	44671.00	33215.00	11456.00	1:1.34
T8	RDF +FYM 5t/ha +Rhizobium + PSB inoculation	1210.00	1428.00	46634.00	18865.00	27769.00	1:2.47



The economic evaluation of different soybean treatments highlights the impact of various fertilizer and inoculation applications on yield, cost, and profitability. "The study assessed eight treatments based on grain and straw yield, gross return, cost of cultivation, net profit, and the benefit-cost (B:C) ratio. Among all treatments, T4 (RDF + Ammonium Molybdate @ 1g/kg seed + Rhizobium + PSB inoculation) recorded the highest grain yield (1,255 kg/ha) and straw yield (1,456 kg/ha), leading to the highest gross return (₹48,293/ha). This was followed by T3 (₹46,230/ha) and T8 (₹46,634/ha), which also exhibited higher yields. The lowest gross return (₹38,953/ha) was recorded in T1 (control with only RDF application) due to its relatively lower grain (1,010 kg/ha) and straw yield (1,201 kg/ha). The total cost of cultivation varied depending on the type of amendments used. T7 (RDF + $MnSO_4$ 25 kg/ha + Rhizobium + PSB inoculation) had the highest cultivation cost (₹33,215/ha) due to the additional expense of manganese sulfate, making it the most expensive treatment, The lowest costs were observed in T1 (₹15,659/ha) and T2 (₹15,865/ha), as these treatments relied on basic fertilizer applications without expensive amendments. T4 (₹16,185/ha) maintained a moderate cultivation cost while yielding the highest returns, making it the most cost-effective treatment. The net profit analysis revealed that T4 was the most profitable treatment, with a net return of ₹32,108/ha and the highest B:C ratio of 1:2.98. This indicates that for every ₹1 spent, the return was ₹2.98, making it the most efficient investment. T3 (₹28,500/ha, B:C ratio 1:2.60) and T8 (₹27,769/ha, B:C ratio 1:2.47) also demonstrated strong profitability. On the other hand, T7 was the least profitable, with the lowest net return (₹11,456/ha) and a B:C ratio of 1:1.34, primarily due to its high input cost that reduced overall economic benefits.

Table 2: Total Revenue Generated from Grain and Straw Yield

Treatment	Grain Yield (kg/ha)	Straw Yield (kg/ha)	Grain Price (₹/kg)	Straw Price (₹/kg)	Total Revenue (₹/ha)
T1	1010	1201	38.00	5.00	38,953
T2	1132	1336	38.00	5.00	43,628
T3	1200	1410	38.00	5.00	46,230
T4	1255	1456	38.00	5.00	48,293
T5	1170	1392	38.00	5.00	45,126
T6	1149	1356	38.00	5.00	44,283
T7	1160	1357	38.00	5.00	44,671
T8	1210	1428	38.00	5.00	46,634

The total revenue from soybean production was determined by considering the market prices of both grain and straw. Among all treatments, the highest total revenue (₹48,293/ha) was recorded for T4 (RDF + Ammonium Molybdate @ 1g/kg seed + Rhizobium + PSB inoculation) due to its superior grain (1,255 kg/ha) and straw (1,456 kg/ha) yields. The second-highest revenue (₹46,634/ha) was obtained in T8 (RDF + FYM 5t/ha + Rhizobium + PSB inoculation), followed by T3 (RDF + $ZnSO_4$ 50 kg/ha + Rhizobium + PSB inoculation, ₹46,230/ha). The lowest revenue (₹38,953/ha) was recorded for T1 (control treatment with only RDF 20:60:20:20 kg/ha), as it had the lowest grain and straw yields.

Table 3: Total Cost Incurred for Fertilizers, Amendments, and Cultivation

Treatment	Fertilizer Cost (₹/ha)	Biofertilizer Cost (₹/ha)	Micronutrient Cost (₹/ha)	Other Costs (₹/ha)	Total Cost (₹/ha)
T1	8200	-	-	7459	15,659
T2	8200	1200	-	7465	15,865
T3	8200	1200	3830	7500	17,730
T4	8200	1200	2285	7500	16,185
T5	8200	1200	5045	7500	19,745
T6	8200	1200	5465	7500	20,165
T7	8200	1200	15,515	7500	33,215
T8	8200	1200	3165	7500	18,865

The cost of cultivation varied significantly based on the treatments applied. T7 (RDF + $MnSO_4$ 25 kg/ha + Rhizobium + PSB inoculation) had the highest total cost (₹33,215/ha) due to the additional expense of $MnSO_4$ amendment. On the other hand, T1 (₹15,659/ha) and T2 (₹15,865/ha) had the lowest cultivation costs since they involved only basic fertilizer applications. T4 (₹16,185/ha), which produced the highest revenue, maintained a moderate cost of cultivation, making it a cost-effective option. Treatments incorporating micronutrients such as $FeSO_4$, $ZnSO_4$, and Borax exhibited higher costs than those using only biofertilizers.

Table 4: Profitability in Terms of Net Return and B:C Ratio

Treatment	Total Revenue (₹/ha)	Total Cost (₹/ha)	Net Return (₹/ha)	B:C Ratio
T1	38,953	15,659	23,294	1:2.48
T2	43,628	15,865	27,763	1:2.74
T3	46,230	17,730	28,500	1:2.60
T4	48,293	16,185	32,108	1:2.98
T5	45,126	19,745	25,381	1:2.28
T6	44,283	20,165	24,118	1:2.19
T7	44,671	33,215	11,456	1:1.34
T8	46,634	18,865	27,769	1:2.47

The economic viability of each treatment was assessed by computing the net return and benefit-cost (B:C) ratio. T4 (RDF + Ammonium Molybdate @ 1g/kg seed + Rhizobium + PSB inoculation) recorded the highest net return of ₹32,108/ha, with a B:C ratio of 1:2.98, making it the most profitable treatment. This was followed by T3 (₹28,500/ha, B:C ratio 1:2.60) and T8 (₹27,769/ha, B:C ratio 1:2.47). The lowest net return was observed in T7 (₹11,456/ha, B:C ratio 1:1.34) due to its high input costs, making it the least profitable. While T5 and T6 also produced reasonable net returns, their B:C ratios remained lower than T4, suggesting that the additional amendments used in these treatments may not have resulted in proportionate economic benefits."

Discussion

The present study aimed to evaluate the economic viability of different soybean treatments by assessing their impact on grain and straw yield, gross returns, cost of cultivation, net profit, and benefit-cost (B:C) ratio. The results demonstrated that the application of RDF in combination with bio-inoculants and micronutrients significantly influenced soybean yield and profitability. Mohankumar, H. K. (2010) [1].

Among all treatments, T4 (RDF + Ammonium Molybdate @ 1g/kg seed + Rhizobium + PSB) recorded the highest net return (₹32,108) and B:C ratio (1:2.98), indicating its superior economic efficiency. This can be attributed to enhanced nitrogen fixation and phosphorus solubilization, leading to improved nutrient availability and plant growth. The second most profitable treatments were T8 (RDF + FYM 5t/ha + Rhizobium + PSB) and T3 (RDF + $ZnSO_4$ 50 kg/ha + Rhizobium + PSB), yielding net returns of ₹27,769 and ₹28,500, respectively, with relatively high B:C ratios. These results suggest that the incorporation of organic amendments and essential micronutrients can further enhance yield and economic returns. Singh (2010)

Conversely, the least profitable treatment was T7 (RDF + $MnSO_4$ 25 kg/ha + Rhizobium + PSB), which resulted in the lowest net return (₹11,456) and a poor B:C ratio of 1:1.34. The high cost of manganese sulfate and its comparatively lower yield benefits likely contributed to this lower profitability. Similarly, T6 (RDF + $FeSO_4$ 10 kg/ha + Rhizobium + PSB) also exhibited lower economic returns, suggesting that iron supplementation alone may not be as beneficial for soybean yield enhancement compared to other nutrient combinations.

Conclusion

This study evaluated the economic impact of different agronomic treatments on soybean production, considering grain and straw yield, gross returns, cost of cultivation, net profit, and the benefit-cost (B:C) ratio. The results clearly indicate that integrating RDF with bio-inoculants and select micronutrients significantly enhances soybean productivity and profitability. Among all treatments, T4 (RDF + Ammonium Molybdate @ 1g/kg seed + Rhizobium + PSB) emerged as the most economically viable option, yielding the highest net return (₹32,108) and B:C ratio (1:2.98). This highlights the importance of ammonium molybdate in promoting nitrogen fixation and phosphorus solubilization, leading to improved crop growth. Additionally, T8 (RDF + FYM 5t/ha + Rhizobium + PSB) and T3 (RDF + $ZnSO_4$ 50 kg/ha + Rhizobium + PSB) also showed promising results with net returns above ₹28,500 and favorable B:C ratios, indicating the benefits of organic amendments and zinc supplementation. In contrast, T7 (RDF + $MnSO_4$ 25 kg/ha + Rhizobium + PSB) resulted in the lowest net return (₹11,456) and a poor B:C ratio (1:1.34), suggesting that manganese application alone may not provide sufficient economic benefits. Similarly, T6 (RDF + $FeSO_4$ 10 kg/ha + Rhizobium + PSB) also showed lower profitability. Overall, the study underscores the significance of integrated nutrient management in soybean cultivation. The findings suggest that a well-balanced combination of fertilizers, bio-inoculants, and essential micronutrients can optimize yield and maximize economic returns for farmers, contributing to sustainable and profitable soybean production.

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