



RESEARCH ARTICLE

Impact of intercropping and bio-enhancers on growth, yield and economic attributes of broccoli

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Abstract

Broccoli (*Brassica oleracea* var. *italica* L.) is one of the most important cool season vegetables of the Brassicaceae family. Broccoli, a member of the Cole group, originates from the Mediterranean region. This study aimed to examine the effect of different bio-enhancers on a broccoli based intercropping system. The experiment was laid out in a factorial randomized block design (FRBD) with three replications comprising fifteen treatment combinations. Coriander (*Coriandrum sativum*) and fenugreek (*Trigonella foenum-graecum* L.) were used as intercrop along with panchagavya and ogran at different doses as bio-enhancers. Intercropping of broccoli with fenugreek and foliar spray of Panchagavya @ 3 % showed the best results in growth and yield parameters, including plant height (62.12 cm), plant spread (64.43 cm), stalk length (17.56 cm) and leaf area (804.28 cm²). It also recorded the lowest days to head initiation (48.56 days) and the highest head length (18.51 cm), number of sprouts per plant (8.89) and head yield per hectare (16.81 t). Combination of broccoli + fenugreek intercropping with foliar spray of Panchagavya at 3 % also had a significant effect on economic attributes, recording the highest net return (₹196149.35) and benefit: cost ratio (2.03).

Keywords: *Brassica oleracea* var. *italica* L; economics; intercropping; panchagavya

Introduction

Broccoli (*Brassica oleracea* var. *italica* L.), is an important cool season vegetable of the Brassicaceae family, possessing 18 chromosomes (2n=18). Broccoli is an Italian word originated from Latin 'Brachium' meaning an arm or branch (1). Furthermore, broccoli flavonoids have been shown to protect against cancer and HIV infection and broccoli's high chlorophyll content may help to prevent cancer, DNA damage and cardiovascular disease (2). One of the key methods for increasing crop production vertically and cropping intensity in developing nations is intercropping, which is the practice of growing two or more crops concurrently on the same plot of land. Effective intercropping maintains soil fertility while simultaneously increasing productivity (3). Bio-enhancers are organic preparations made by actively fermenting animal and plant residues for a set period of time. Bio-enhancers are commonly used to treat seeds and seedlings, stimulate organic matter decomposition, enrich the soil and improve plant vigour (4). Panchagavya is a Sanskrit term that refers to a mixture or blend of five products obtained from cows, including ghee, milk, curd, cow dung and cow urine. Ogran is a bio-enhancer produced from organic raw materials like kitchen waste, rotten fruits and

vegetables through natural process. It is a micronutrient solution and fertilizer which improve the quality and production of flowers, vegetables and fruits.

Simultaneously, the use of bio-enhancers organic formulations including biofertilizers, plant growth-promoting rhizobacteria (PGPR), composts and microbial consortia has emerged as a viable alternative to synthetic agrochemicals. These inputs enhance nutrient availability, stimulate plant growth and improve soil health, thus contributing to higher yield and better crop quality. This study aims to investigate the combined effects of intercropping and bio-enhancers on the growth performance, yield attributes and economic viability of broccoli production. By integrating these sustainable practices, the research seeks to contribute to the development of cost-effective and environmentally friendly cultivation techniques that align with modern agricultural demands.

Materials and Method

The experiment was conducted during the winter seasons of 2019-2020 and 2020-2021 at Experimental Farm, Department of Agriculture, Mata Gujri College, Fatehgarh Sahib, Punjab is

situated between 76° - 22'E to 76°- 46'E latitude and 30° - 36'N to 30° - 39'N longitudes and at a mean height of 279 m above sea level. The climate of Fatehgarh Sahib is sub-tropical and semi-arid with temperature range of minimum recorded up to 11 °C in the month of December-January while maximum goes high as 45 °C in the month of May-June. The experiment consisted of 15 treatments laid out in a FRBD with three replications. The experiment contains 15 combinations of two factors with the first factor being different intercrops with 3 levels viz. C₁- broccoli (sole crop), C₂- broccoli + coriander and C₃ - broccoli + fenugreek and the second is bio-enhancers with 5 levels viz. B₀- No bio enhancer, B₁- Panchgavyaat %, B₂ - Panchgavya @1.5 %, B₃ - Ogronat@3 % and B₄ - Ogronat@1.5 %. The seedling was raised at Mata Gujri College, Fatehgarh Sahib under special care in 31 x 0.15 seed bed. Sowing of nursery was done on 29th September 2019 and 26th September 2020. The seedlings were ready for transplanting within 28 days of sowing.

Fenugreek and coriander were sown in the main field after one week of transplanting of broccoli seedlings. Fenugreek and coriander seeds were directly sown with a row-to-row spacing of 30 cm. The seeds were sown on 5th November 2019 and 2nd November 2020 followed by light irrigation. Panchagavya was prepared by mixing fresh cow dung, cow ghee, cow urine, cow milk, cow curd and water. The container was covered with a thin cloth and kept in shade. During incubation, the mixture was stirred twice daily. After 15 days, the panchagavya was ready for field application. In the end, the mixture was filtered through a muslin cloth (5). Bio-enhancers were applied topically at 20 and

40 days after transplantation. Nine plants were randomly chosen from each plot and tagged to assess the effect of intercropping systems and bio-enhancers on growth and yield. The experiment's results were examined in accordance with Panse and recommendations for experiment design (6). The significance of differences among treatment means was tested at the 5 % probability level.

Results and Discussion

The investigation's findings demonstrated that the intercropping system and bio-enhancer significantly varied at various phases of broccoli growth. The highest plant height 58.68 cm, plant spread 60.91 cm, number of leaves per plant 19.36 was obtained at all the growth stages in C₃(broccoli + fenugreek) (Table 1). The favorable effects of manuring, irrigation and other management activities in the interspaces of broccoli due to reduced competition between main and intercrop may be responsible for the increase in plant height (7). The increased leaf count could be attributed to the primary crop making better use of available resources (8). The maximum plant height 57.36 cm plant spread 57.67 cm, number of leaves per plant 18.63 was obtained at all the growth stages in B₁(panchagavya @ 3 %) (Table 1). Promoted protein synthesis and growth regulators like IAA and GA₃ in panchagavya may have promoted cell division, cell multiplication and cell enlargement, which favors higher inter nodal length, contributing to the increase in plant height (9). By improving soil nutrient uptake, solubilization and mobilization of the insoluble form of phosphorus by organic acids, Panchagavya improved the number of leaves (10).

Table 1. Effect of bio-enhancer and intercropping on plant height (cm), plant spread (cm), number of leaves plant⁻¹, leaf length (cm), leaf width (cm)

Treatment combination	Plant height (cm)	Plant spread (cm)	Number of leaves plant ⁻¹	Leaf length (cm)	Leaf width (cm)
Intercrop (C)					
C ₁	49.36	46.29	16.47	42.57	18.54
C ₂	54.97	54.44	17.75	45.57	20.34
C ₃	58.68	60.91	19.36	48.26	22.60
SEm(±)	0.46	0.73	0.16	0.31	0.22
CD (0.05 %)					
Bio-enhancer (B)					
B ₀	49.94	47.62	16.16	42.78	19.23
B ₁	57.36	57.67	18.63	47.18	21.40
B ₂	56.50	56.62	18.27	46.61	20.99
B ₃	54.94	54.99	18.21	45.84	20.82
B ₄	52.96	52.50	18.02	44.92	20.03
SEm(±)	0.60	0.95	0.21	0.41	0.29
CD (0.05 %)					
Interaction (CXB)					
C ₁ B ₀	45.63	45.75	13.56	41.67	18.29
C ₁ B ₁	51.59	47.12	17.30	43.09	18.94
C ₁ B ₂	51.52	46.74	17.29	42.98	18.56
C ₁ B ₃	51.35	46.26	17.26	42.86	18.51
C ₁ B ₄	46.73	45.59	16.93	42.27	18.39
C ₂ B ₀	51.95	48.55	17.37	43.32	19.62
C ₂ B ₁	58.36	61.46	18.40	47.97	20.62
C ₂ B ₂	58.03	58.72	17.73	47.12	20.60
C ₂ B ₃	53.61	54.51	17.64	45.44	20.50
C ₂ B ₄	52.91	48.97	17.59	43.99	20.37
C ₃ B ₀	52.24	48.57	17.54	43.36	19.78
C ₃ B ₁	62.12	64.43	20.20	50.46	24.63
C ₃ B ₂	59.96	64.41	19.79	49.73	23.81
C ₃ B ₃	59.85	64.19	19.74	49.23	23.44
C ₃ B ₄	59.24	62.94	19.53	48.51	21.35
SEm(±)	1.04	1.64	0.36	0.70	0.50

C₁ - broccoli (sole crop), C₂- broccoli+coriander, C₃ - broccoli+fenugreek, B₀ - No- Bio enhancer, B₁ - Panchgavya@3 %, B₂ - Panchgavya@1.5 %, B₃ - ogron @3 %, B₄ - ogron@1.5

Maximum leaf length 48.26 cm and leaf width 22.60 cm was recorded in C₃ (broccoli + fenugreek) as shown in Table 1. This could be due to atmospheric nitrogen fixation because fenugreek is a leguminous crop with a tiny canopy that did not interfere with the main crop's growth (11). Longest leaf length 47.18 cm and leaf width 21.40 cm was recorded in B₁ (Panchagavya@3 %) (Table 1). The presence of naturally occurring beneficial microorganisms in panchagavya, such as lactic acid bacteria, yeast, actinomycetes, photosynthetic bacteria and some fungi, which aid in the plant's development more vegetatively, may explain the increased leaf length and width (12).

Highest plant stalk length 16.11 cm and leaf area 762.96 cm² was recorded by the treatment C₃ (broccoli + fenugreek) (Table 2). The increased stalk length amid intercropping may be owing to the beneficial management activities in the interspaces of broccoli due to decreased rivalry between the primary and intercrop (13). Intercropping's ability to manage weeds, lessen water and nutrient competition between cultivated plants and weeds and encourage the growth of cultivated plants may be responsible for the increased leaf area (14). Maximum plant stalk length 15.25 cm and maximum leaf area 732.78 cm² were observed under treatment B₁(Panchagavya@3 %) as shown in Table 2. Panchagavya contains growth enzymes that promote rapid cell division and multiplication (9). In both favorable and unfavorable growing conditions, Panchagavya's abundant microbial metabolites help maintain stomata open for extended periods of time, increasing leaf area (15). The lowest days to head initiation (52.23) and maturity (58.41) were recorded by the

treatment C₃ (broccoli + fenugreek) (Table 2). This might be because growing broccoli alone required more nutrients, such as nitrogen fertilizers, which slowed down plant growth and curd maturation, but growing broccoli with fenugreek produces the shortest curd initiation and maturity days (16). The minimum days to head initiation (54.38) and maturity (60.09) was observed under treatment B₁ (Panchagavya@3 %) (Table 2). IAA, GA₃ and cytokinin among other growth-stimulating compounds, may encourage the transfer of more photo-assimilates to reproductive areas, causing early head development and maturity in plants (17). Maximum head length (17.53 cm), head diameter (16.26 cm) (Table 3) and biological yield (1.09 g) (Table 2) was recorded in C₃ (broccoli + fenugreek). Increased head length may be related to lower plant density and better use of available N fixed by fenugreek roots, allowing the plant to produce its vegetative parts quickly (18). As fenugreek is a leguminous crop with a small canopy that did not interfere with the main crop's growth, head diameter increase may be attributed to atmospheric nitrogen fixation (11). Increase in biological yield is that the fenugreek as an intercrop acted as a complement to the main crop, assisting it in achieving higher productivity per unit area (19). Among bio-enhancers, B₁ (Panchagavya@3 %) resulted in maximum head length (16.65 cm), head diameter (15.31 cm) (Table 3) and biological yield (1.04 g) (Table 2). The presence of enough macro and micronutrients, enhanced nutrient uptake, higher vegetative development and subsequent portioning and translocation from the leaf to the head as well as the release of energizing substances by organic formulations could all contribute to this

Table 2. Effect of bio-enhancer and intercropping on leaf area (cm²), stalk length (cm), days taken to head initiation (days), days taken to head maturity (days), biological yield (g plant⁻¹) (pooled data)

Treatment combination	Leaf area (cm ²)	Stalk length (cm)	Days taken to head initiation (Days)	Days taken to head maturity (Days)	Biological yield
			Intercrop (C)		
C ₁	599.76	12.88	58.93	65.51	0.90
C ₂	691.35	14.58	57.14	62.61	1.00
C ₃	762.96	16.11	52.23	58.41	1.09
SEm(±)	8.18	0.17	0.51	0.47	0.01
CD (0.05 %)	23.70	0.48	1.49	1.35	0.02
			Bio-enhancer (B)		
B ₀	602.83	13.58	58.53	64.62	0.93
B ₁	732.78	15.25	54.38	60.09	1.04
B ₂	713.39	15.06	54.74	61.08	1.03
B ₃	707.48	14.75	55.40	61.72	1.01
B ₄	666.96	13.97	57.44	63.38	0.99
SEm(±)	10.56	0.21	0.66	0.60	0.01
CD (0.05 %)	30.10	0.61	1.89	1.72	0.03
			Interaction (CXB)		
C ₁ B ₀	520.09	12.43	60.38	66.39	0.88
C ₁ B ₁	635.61	13.27	57.99	64.73	0.93
C ₁ B ₂	634.18	13.13	58.23	65.09	0.92
C ₁ B ₃	625.60	13.01	58.59	65.60	0.90
C ₁ B ₄	583.33	12.55	59.43	65.75	0.89
C ₂ B ₀	642.79	14.10	57.79	63.89	0.94
C ₂ B ₁	717.25	14.93	56.58	61.67	1.05
C ₂ B ₂	701.70	14.90	56.74	61.76	1.03
C ₂ B ₃	699.22	14.73	57.28	62.44	1.00
C ₂ B ₄	695.80	14.22	57.29	63.32	0.99
C ₃ B ₀	645.62	14.20	57.40	63.60	0.96
C ₃ B ₁	845.48	17.56	48.56	53.87	1.15
C ₃ B ₂	804.28	17.14	49.24	56.38	1.14
C ₃ B ₃	797.64	16.50	50.33	57.13	1.12
C ₃ B ₄	721.77	15.15	55.61	61.06	1.09
SEm(±)	18.30	0.37	1.15	1.05	0.02
CD (0.05 %)	52.99	1.07	3.33	3.03	0.05

C₁ - broccoli (sole crop), C₂ - broccoli+coriander, C₃ - broccoli+fenugreek, B₀ - No- Bio enhancer, B₁ - Panchgavya@3 %, B₂ - Panchgavya@1.5 %, B₃ - ogran @3 %, B₄ - ogran@1.5

Table 3. Effect of bio-enhancer and intercropping on head length (cm), head diameter (cm), number of sprout plant⁻¹, weight of sprout (g plant⁻¹), harvest index (%) (pooled data)

Treatment combination	Head length (cm)	Head diameter (cm)	Number of sprout plant ⁻¹	Weight of sprout (g plant ⁻¹)	Harvest index (%)
Intercrop (C)					
C ₁	14.11	13.87	6.50	153.76	28.13
C ₂	15.67	14.56	7.45	163.15	30.66
C ₃	17.53	16.26	8.36	175.67	29.91
SEm(±)	0.19	0.15	0.09	1.40	0.44
CD (0.05 %)	0.54	0.42	0.27	4.07	1.28
Bio-enhancer (B)					
B ₀	14.51	14.05	6.64	156.90	28.45
B ₁	16.65	15.31	7.82	170.92	30.11
B ₂	16.20	15.16	7.72	166.85	29.92
B ₃	15.97	15.01	7.59	165.34	29.82
B ₄	15.52	14.96	7.43	160.96	29.52
SEm(±)	0.24	0.19	0.12	1.81	NS
CD (0.05 %)	0.68	0.54	0.34	5.17	
Interaction (CXB)					
C ₁ B ₀	13.43	13.53	6.20	151.33	23.12
C ₁ B ₁	14.62	14.13	6.79	157.97	30.44
C ₁ B ₂	14.46	14.04	6.70	154.48	30.13
C ₁ B ₃	14.26	13.85	6.45	152.92	29.37
C ₁ B ₄	13.78	13.79	6.37	152.12	27.57
C ₂ B ₀	15.05	14.25	6.85	159.08	30.99
C ₂ B ₁	16.83	14.94	7.77	166.53	30.58
C ₂ B ₂	15.81	14.72	7.73	164.86	30.23
C ₂ B ₃	15.54	14.45	7.59	162.97	30.71
C ₂ B ₄	15.13	14.45	7.34	162.33	30.80
C ₃ B ₀	15.06	14.36	6.89	160.30	31.25
C ₃ B ₁	18.51	16.87	8.89	188.26	29.30
C ₃ B ₂	18.32	16.72	8.74	181.23	29.41
C ₃ B ₃	18.11	16.71	8.72	180.12	29.37
C ₃ B ₄	17.64	16.65	8.58	168.45	30.21
SEm(±)	0.41	0.33	0.21	3.14	0.99
CD (0.05 %)	1.20	0.94	0.60	9.10	2.86

(20). Increases in dry matter accumulation, chlorophyll content, nitrate reductase activity and provision of all plant nutrients may be related with the greatest improvement in biological yield with all foliar sources (21).

Highest number of sprouts per plant was 8.36 and weight of sprout 175.67 g was observed in C₃(broccoli + fenugreek) (Table 3). Leguminous fenugreek's nitrogen fixation had a substantial impact on the number of sprouts per plant (22). Plants could develop their vegetative parts quickly due to lower plant density and greater use of available N fixed by fenugreek roots (23). Among the various bio-enhancers maximum no. of sprout plant 7.82 and weight of sprout per plant 170.92 g was taken under B₁(Panchagavya@3 %) (Table 3). The increase of cytokinin and auxin in their auxiliary buds may have favoured the plants to produce more sprouts per plant (24). The cow dung in panchagavya acts as a medium for the growth of beneficial bacteria and cow urine delivers nitrogen, which is needed for crop growth, may also account for the increase in yield (25, 26). The highest harvest index (30.66 %) was recorded in C₂ (broccoli + coriander) (Table 3). Intercrops covering the interspaces between the main crops at the same time may have helped with weed control, as well as enhanced soil moisture conservation, accumulation and delivery throughout the end period (27). Within the bio-enhancers the data regarded harvest index showed a non-significant effect during both seasons. Similar findings were recorded by (28). Highest average head weight 322.79 g, head yield per plot (12.46 kg) and head yield ha⁻¹ (16.19 t) was observed in C₃ (broccoli + fenugreek) (Table 4). Lower plant density and better use of available N fixed by fenugreek roots, allowing the plant to produce its vegetative

parts quickly, resulting in maximum output (19). Among bio-enhancers, B₁ (Panchagavya@3 %) observed maximum average head weight 313.81 g, head yield per plot plot⁻¹ 11.98 kg, head yield per ha ha⁻¹ 15.74 t (Table 4). The rise in head weight of broccoli could be related to improved chlorophyll pigment efficiency, which produces more photosynthates and increases photosynthate allocation in the economic section (26). This could be owing to the nutrients in the panchagavya i.e. macronutrients like nitrogen, phosphorus and potassium as well as micronutrients, all of which are necessary for plant growth and development. The presence of various amino acids, vitamins, growth regulators like auxins, gibberellins and cytokinin, as well as beneficial microorganisms such as Pseudomonas, Azotobacter and phosphobacteria, which influenced the yield attributes (5).

Every farmer's goal is to maximize net income per hectare after deducting cultivation costs. Maximum marketable output of healthy heads of specified treatments was the reason for enhanced profit and benefit:cost ratio. Data collected on economic characteristics, the highest net income per hectare (₹196149.35) and maximum B:C ratio (2.03) were calculated with C₃B₁ [(broccoli + fenugreek) + Panchagavya@3 %] (Table 5). Increased benefit: cost ratio is due to higher gross returns and low cost of cultivation (29). Panchagavya had a greater B: C ratio than other organic bio-enhancers because cattle dung and urine are inexpensive materials that farmers can find in their homes.

Table 4. Effect of bio-enhancer and intercropping on average head weight (g ha⁻¹), head yield (kg plot⁻¹), head yield (t ha⁻¹) (pooled data)

Treatment combination	Average head weight (g ha ⁻¹)	Head yield (kg plot ⁻¹)		Head yield (t ha ⁻¹)
		Intercrop (C)	Bio-enhancer (B)	
C ₁	261.60	9.56		12.61
C ₂	308.72	11.68		15.46
C ₃	322.79	12.46		16.19
SEm(±)	3.22	0.14		0.17
CD (0.05 %)	9.32	0.41		0.50
Interaction (CXB)				
C ₁ B ₀	208.58	7.82		10.33
C ₁ B ₁	288.93	10.78		14.41
C ₁ B ₂	283.37	10.23		13.53
C ₁ B ₃	273.51	9.84		12.90
C ₁ B ₄	253.61	9.14		11.85
C ₂ B ₀	297.15	11.50		14.92
C ₂ B ₁	319.51	11.99		15.99
C ₂ B ₂	312.83	11.79		15.86
C ₂ B ₃	309.19	11.63		15.37
C ₂ B ₄	304.91	11.50		15.17
C ₃ B ₀	302.37	11.43		14.98
C ₃ B ₁	333.00	13.16		16.81
C ₃ B ₂	330.66	12.97		16.49
C ₃ B ₃	325.39	12.64		16.39
C ₃ B ₄	322.54	12.09		16.27
SEm(±)	7.19	0.32		0.39
CD (0.05 %)	20.83	0.92		1.13

Table 5. Effect of bio-enhancer and intercropping on economic attributes of broccoli (Pooled data)

Treatment	Total cost (₹)	Gross return (₹)	Net return (₹)	B: C ratio
C ₁ B ₀	71584.00	103333.33	31749.33	0.44
C ₁ B ₁	78402.50	144133.33	65730.83	0.84
C ₁ B ₂	74993.25	135300.00	60306.75	0.80
C ₁ B ₃	89997.72	129033.33	39035.61	0.43
C ₁ B ₄	80790.86	118533.33	37742.47	0.47
C ₂ B ₀	87184.00	196676.54	109492.54	1.26
C ₂ B ₁	94002.50	246908.64	152906.14	1.63
C ₂ B ₂	90593.25	239925.93	149332.68	1.65
C ₂ B ₃	105597.72	228622.22	123024.50	1.17
C ₂ B ₄	96390.86	224361.73	127970.87	1.33
C ₃ B ₀	89684.00	207312.35	117628.35	1.31
C ₃ B ₁	96502.50	292651.85	196149.35	2.03
C ₃ B ₂	93093.25	273008.64	179915.39	1.93
C ₃ B ₃	108097.72	268203.70	160105.98	1.48
C ₃ B ₄	98890.86	257256.17	158365.31	1.60

C₁ - broccoli (sole crop), C₂ - broccoli+coriander, C₃ - broccoli+fenugreek, B₀ - No- bio enhancer, B₁ - Panchgavya@3 %, B₂ - Panchgavya@1.5 %, B₃ - ogran@3 %, B₄ - ogran@1.5 %

Conclusion

The present study clearly demonstrates that the intercropping system and application of bio-enhancers significantly influenced the growth, yield and economic return of broccoli. Among the intercropping treatments, C3 (broccoli + fenugreek) consistently outperformed others, showing the highest values for plant height, plant spread, number of leaves, leaf dimensions, stalk length, leaf area and yield parameters such as head size, biological yield, number of sprouts and average head weight. The beneficial effects can be attributed to reduced competition, nitrogen fixation by fenugreek and enhanced resource utilization.

Similarly, among the bio-enhancer treatments, B1 (Panchgavya @ 3 %) resulted in significant improvements in vegetative and reproductive traits of broccoli, likely due to its rich content of growth-promoting substances, beneficial

microorganisms and essential nutrients. The combination treatment C3B1 (broccoli + fenugreek with Panchagavya @ 3 %) yielded the highest net income per hectare and benefit:cost ratio, demonstrating superior agronomic and economic performance.

Therefore, intercropping broccoli with fenugreek along with the foliar application of Panchagavya @ 3 % is recommended as an effective and sustainable cultivation strategy to enhance productivity, profitability and resource-use efficiency in broccoli cultivation.

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Authors' contributions

Writing the original draft, visualization and conceptualization were done by GK and DS. Writing the review, editing and conceptualization were performed by SKS, DT, SS and RN. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors have no conflicts of interest to declare. All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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