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Effect of prom, sulphur and iron on growth, yield and quality of groundnut

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Abstract
A field experiment was conducted at Agronomy Instructional Farm, Department of Agronomy, Chimanbhai Patel College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar to study the effect of PROM, sulphur and iron on growth yield and quality of groundnut during two consecutive *kharif* season of the year 2022 and 2023. The pooled results indicated that an application of 375 kg PROM/ha (P_3) and 37.5 kg sulphur/ha (S_3) recorded significantly higher growth, yield attributes and yield parameters *viz*., plant height, number of root nodules, fresh and dry weight of root nodules, number of pods and filled pods per plant, pod and haulm yield of groundnut. Furthermore, quality parameters such as oil content, oil yield, protein content and protein yield of kernel were also significantly improved at these levels compared to lower doses. Regarding the iron levels, the highest application rate of 6.0 kg iron/ha (Fe_3) resulted in significantly increased yield attributes and yield *viz*., number of pods and filled pods per plant, pod and haulm yields of *kharif* groundnut quality parameters *viz*., oil content, protein content and protein yield of kernel as compare to lower iron levels.

Keywords: Groundnut, PROM, sulphur, iron, growth, yield, quality

Introduction
India is the third largest producer of oilseeds in the world. It ranks first in the production of groundnut and sesamum and second in rape-seed and mustard. The self-sufficiency in oilseeds attained through "Yellow Revolution" during early 1990's, could not be sustained beyond a short period. Although India has 20 per cent of the world oilseed area, it produces less than 10.9 per cent world's edible oils to meet the needs of about 16 per cent of the world's population, hence the oil production and per capita oil availability in India is very low.

Groundnut is important crop in human and animal nutrition, because it is a major source of edible vegetable oil and high protein feed as well as food in the world. It is an excellent health food and contains 20-22% quality protein, 23% carbohydrates and 40-45% cholesterol free oil. Groundnut protein is rich in valuable amino acid *viz*., lysine (5%) which is deficient in most of the cereals. It also contains 60% poly unsaturated fatty acid (52.8% linoleic acid + 7.2% linolenic acid). Groundnut is a good source of all vitamins B except B_{12}. They are a rich source of thiamine, riboflavin, nicotinic acid and vitamin E. It has high calorific value releasing 432 calories from 100 gm edible protein as compared to 350 calories from cereal of same quantity.

The growth, yield, and quality of groundnut are significantly influenced by various agronomic practices, including the application of macro and micronutrients. Among these, phosphorus (P), sulphur (S) and iron (Fe) are vital nutrients that play critical roles in groundnut physiology. Phosphorus is essential for root development, energy transfer and overall plant vigor. Sulphur is a key component of certain amino acids and vitamins, contributing to protein synthesis and oil quality. Iron, though required in smaller quantities, is crucial for chlorophyll formation and enzymatic functions. A deficiency or imbalance of these nutrients can lead to suboptimal growth and reduced yield, impacting both the quantity and quality of the produce.

Despite the known importance of P, S and Fe, there is limited comprehensive research on their combined effect on groundnut crops.

Understanding the synergistic and individual roles of these nutrients can help optimize fertilization strategies, enhance crop productivity, and improve the quality of groundnut seeds, which are highly valued for their oil content and nutritional properties.

Materials and Methods

The field experiment was laid out on fixed site of plot number C-18 during *kharif* season of 2022 and 2023 at Agronomy instructional farm, CP College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Banaskantha (Gujarat). The topography of the experimental site was fairly uniform and levelled. The data of soil analysis indicated that the soil of the experimental field was loamy sand in texture, low in organic carbon and available nitrogen, medium in available phosphorus, potash and sulphur and DTPA-extractable iron, manganese and zinc and high in DTPA extractable Cu content in soil. EC was normal showing that soil was free from salinity hazard. There were twenty seven treatment combinations comprising each of three levels of PROM *i.e.*, P_1: 125 kg PROM/ha, P_2: 250 kg PROM/ha and P_3: 375 kg PROM/ha, sulphur *i.e*., S_1: 12.5 kg sulphur/ha, S_2: 25.0 kg sulphur/ha and S_3: 37.5 kg sulphur/ha and iron *i.e*., Fe_1: 2.0 kg iron/ha, Fe_2: 4.0 kg iron/ha and Fe_3: 6.0 kg iron/ha were tested in a randomized block design with factorial concept and replicated three time. Common dose of FYM @ 5 t/ha was applied 15 days before the sowing for getting better result of organic manures and nitrogen @12.5 kg/ha was applied through urea. PROM was applied in granular form which contains 10.4% P_2O_5.

Bold and healthy seeds groundnut variety TG 37 A were treated with *Rhizobium* and PSB each @ 5 ml/kg seed as per the treatments were sown at a spacing of 45 cm row apart by maintaining the seed rate of 120 kg/ha and the seeds were sown in previously opened furrow at the depth of 5 to 6 cm and seeds were properly covered with soil and light irrigation was applied in each plot immediately after sowing for the proper seed germination. The growth and yield attributing observations were recorded on five randomly selected tagged plants from each net plot. These plants were marked with proper notations and used for recording observations. The crop was harvested when, it attained physiological maturity. The produce from net plot of each treatment was harvested separately and picking of pods was done manually from the plants. Both pods and plants were allowed to dry under sun and weight of dry pods and haulm recorded from each plot.

Results and Discussions

Effect of PROM

Significantly the higher plant height at harvest, number of root nodules per plant, fresh and dry weight of root nodules at flowering of *kharif* groundnut were registered with the application of 375 kg PROM/ha (P_3) over 125 kg PROM/ha (P_1) but it remained at par with 250 kg PROM /ha (P_2). However, plant population per meter row length at 30 DAS as well as at the time of harvest was not affected significantly under the different levels of PROM. The increased plant height could be attributable to improved root multiplication and nodulation as a result of increased phosphorus availability. Application of PROM has increased the P uptake by plants which improved the number and weight of nodules/plant (Rathor *et al.* 2022) [24]. These results are also supported by Khangarot *et al.* (2022) [13].

The treatment receiving 375 kg PROM/ha (P_3) recorded significantly higher number of pods per plant, filled pods per plant, pod and haulm yields of *kharif* groundnut compared to 125 kg PROM/ha (P_1), but it remained at par with 250 kg PROM/ha (P_2). However, seed index and shelling percentage was not affected significantly under the different levels of PROM. The application of PROM shows a positive effect on yield and yield attributing character of groundnut mainly due to its role in photosynthesis, energy transfer and thereby increased photosynthetic efficiency. Thus, increased total biomass production and translocation of photosynthates toward reproductive part leads to increased flowering and fruiting and ultimately a more number of pods, pod and haulm yield were obtained. The outcome is, in agreement with the findings of Chaudhari (2015) [7], Aechra *et al.* (2017) [1], Yadav *et al.* (2017[b]), Nissa *et al.* (2019), Hangsing *et al.* (2020) [1, 18, 10].

Marked improvement in oil content and oil yield and protein content and protein yield of *Kharif* groundnut kernel was registered under the influence of 375 kg PROM/ha (P_3) over 125 kg PROM /ha (P_1), but it was remained at par with 250 kg PROM /ha (P_2). This might be due to the fact that phosphorus not only supports the energy and metabolic requirements for oil synthesis in groundnut but also contributes to optimal seed quality and development, which are essential for increasing oil yield. These results align closely with the findings of Reddy *et al.* (2019). Additionally, the increase in protein content may be attributed to the protein content in seeds being directly related to their nitrogen (N) content. The application of PROM enhances root nodulation, leading to greater N fixation by plant roots, and consequently, a significant increase in the protein content of seeds compared to the control (Sharma, 2003).

Effect of sulphur

Different levels of sulphur did not exert any significant influences on the plant population per meter row length at 30 DAS as well as at the time of harvest of *kharif* groundnut. Significantly higher plant height, number of root nodules, fresh and dry weight of root nodules per plant at flowering of *kharif* groundnut was registered with the application of 37.5 kg sulphur/ha (S_3) over 12.5 kg sulphur/ha (S_1) but it remained at par with 25.0 kg sulphur/ha (S_2). Sulphur enhances plant height by promoting cell division, enlargement, and elongation, leading to uniform vegetative growth, consistent with findings by Saini (2013) [26], Shelke *et al.* (2014) [28], Meena *et al.* (2015) [16] and Rajanarsimha *et al.* (2021). Additionally, sulphur boosts root nodulation and nitrogen fixation, enhancing nodule metabolism and vital compounds like leghaemoglobin and ATP, as observed by Kumar *et al*. (2008) [14] and Teja *et al.* (2020) [35].

Groundnut crop fertilized with 37.5 kg sulphur/ha (S_3) significantly increased number of pods per plant, filled pods per plant, pod and haulm yield of groundnut compared to 12.5 kg sulphur/ha (S_1), but it remained at par with 25.0 kg sulphur/ha (S_2). There was non-significant influence of varying levels of sulphur on seed index, shelling percentage of groundnut. Maximum availability of sulphur helps in stimulating photosynthesis and seed formation as well as synthesis of sulphur containing amino acids, proteins, chlorophyll, and promoting nodulation may be assigned to increase total biomass production which was finally reflected in increment in pod yield of groundnut. These results are in agreement with the findings of Jat and Ahlawat (2010) [12], Pandey and Pandey (2019) [19] and Ransing *et al.* (2021[a]) [23].

Oil content and oil yield or protein content and protein yield of *kharif* groundnut was registered significantly superior under the application of 37.5 kg S/ha (S_3) over 12.5 kg sulphur/ha (S_1), however it remained at par with treatment S_2: 25.0 kg sulphur/ha in oil and protein content. Moreover, the increase in oil content might be due to an increase in glucoside, which on hydrolysis produces a higher amount of oil. The higher oil yield under the higher levels of sulphur application is the outcome of significantly higher oil content in the kernel and pod yield of groundnut. These results are supported by the findings of Banu *et al.* (2017) [3], Singh *et al.* (2018) [29] and Yadav *et al.* (2020) [41]. Increased sulphur application enhances both protein content and protein yield might be the fact that sulphur is a structural component of protein, which is directly involved in protein bio-synthesis and improved the protein content in the kernel. These results are in agreement with those reported by Tathe (2008) [34], Meena *et al.* (2015) [16], Bulbule *et al*. (2016) [4], Sisodiya *et al.* (2016) [32] and Kumar *et al.* (2017[a]) [15].

Effect of iron

Different levels of iron did not exert any significant influences on the plant population per meter row length at 30 DAS as well as at harvest, plant height at harvest, number of root nodule, fresh and dry weight of root nodules per plant at flowering of *Kharif* groundnut.

An application of 6.0 kg iron/ha (Fe_3) recorded significantly higher number of pods per plant, filled pods per plant, pod and haulm yield of *Kharif* groundnut compared to 2.0 kg iron/ha (Fe_1), but it remained at par with 4.0 kg iron/ha (Fe_2). However, seed index and shelling percentage did not affected significantly due to various levels of iron. Iron enhances cell division, cell elongation process and photosynthetic activity leading to the production and accumulation of more carbohydrates and auxins which favors the retention of more flowers which resulted increase in yield and yield attributing character of groundnut. Similar results were also found by Thakur *et al.* (2010) [36], Vishwakarma *et al.* (2012) [37], Hagari and Pattar (2017) [9] and Chandra *et al.* (2022) [5]. The crop grown under the effect of 6.0 kg iron/ha (Fe_3) accumulated significantly higher oil yield during both the individual year as well as in pooled results and oil content only during pooled results compared to 2.0 kg iron/ha (Fe_1) but it was found at par with 4.0 kg Fe/ha (Fe_2). This might be due to the fact that iron is important in the redox system in the process of photosynthesis as a constituent of several enzymes in the development and function of chloroplast, and protein synthesis which resulted in a positive effect of iron application on these parameters. Similar results were reported by Porkodi *et al.* (2022) [21].

There was a significant influence in protein yield of *kharif* groundnut with the application of 6.0 kg iron/ha (Fe_3) over rest of the treatment. However, protein content did not affected significantly due to various levels of iron. Similar results were obtained by Yadav *et al*. (2016) [39].

Interaction effect

The data presented in Table 4.5 indicated that the treatment combination P_3S_3 (375 kg PROM/ha + 37.5 kg sulphur/ha) recorded significantly higher number of root nodules, number of pods per plant, pod and haulm yield of *Kharif* groundnut compared to rest of the treatment combinations, but it remained at par with P_3S_2 (375 kg PROM/ha + 25.0 kg sulphur/ha) and P_2S_3 (250 kg PROM/ha + 37.5 kg sulphur/ha). The adequate supply of sulphur and phosphorus ensures the balance nutrition by solubilizing more phosphorus as well as some of the other required elements which is necessary for optimum growth and development of groundnut root as well as shoot resulted more development in reproductive parts, ultimately leading to an increased number of root nodules and pods per plant, pod and haulm yield of groundnut. These findings endorse the results of Bairwa *et al.* (2014) [2], Sipai *et al*. (2016) [31], Chaudhari *et al*. (2019) [6] and Hinduja *et al*. (2020) [11].

Oil content and oil yield or protein content and protein yield of *kharif* groundnut was registered significantly superior under the treatment combination of P_3S_3 (375 kg PROM/ha + 37.5 kg sulphur/ha) over rest of the treatment combinations except P_3S_2 (375 kg PROM/ha + 25.0 kg sulphur/ha) and P_2S_3 (250 kg PROM/ha + 37.5 kg sulphur/ha). When sulphur and phosphorus are adequately supplied, their synergistic interaction enhances metabolic processes involved in oil synthesis. Phosphorus provides energy and structural components, while sulphur contributes to the synthesis of proteins and enzymes, as confirmed by Mishra *et al*. (2010) [17].

Table 1: Effect of PROM, sulphur and iron on plant population and plant height of groundnut

Treatments	Plant population (Per metre row length)						Plant height (cm)		
	At 30 DAS			At harvest			At harvest		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
PROM levels (P)									
P_1: 125 kg/ha	9.82	9.66	9.74	9.22	9.29	9.25	40.70	42.66	41.68
P_2: 250 kg/ha	9.52	9.94	9.73	9.34	9.55	9.44	43.39	43.71	43.55
P_3: 375 kg/ha	9.90	9.91	9.90	9.52	9.46	9.49	44.58	45.26	44.92
S.EM.±	0.13	0.15	0.10	0.13	0.16	0.10	0.806	0.720	0.540
C.D. at 5%	NS	NS	NS	NS	NS	NS	2.29	2.04	1.52
Sulphur levels (S)									
S_1: 12.5 kg/ha	9.61	9.76	9.68	9.40	9.38	9.39	42.04	40.80	41.42
S_2: 25.0 kg/ha	9.75	9.93	9.84	9.24	9.51	9.37	43.02	44.63	43.83
S_3: 37.5 kg/ha	9.89	9.82	9.85	9.44	9.42	9.43	43.62	46.20	44.91
S.EM.±	0.13	0.15	0.10	0.13	0.16	0.10	0.806	0.720	0.540
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	2.04	1.52
Iron levels (Fe)									
Fe_1: 2.0 kg/ha	9.66	9.84	9.75	9.36	9.34	9.35	42.41	42.80	42.61
Fe_2: 4.0 kg/ha	9.81	9.77	9.79	9.30	9.47	9.39	43.28	43.71	43.49
Fe_3: 6.0 kg/ha	9.78	9.90	9.84	9.41	9.49	9.45	42.98	45.12	44.05
S.EM.±	0.13	0.15	0.10	0.13	0.16	0.10	0.81	0.72	0.54
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Significant interaction	-	-	-	-	-	-	-	-	-
CV%	7.10	7.93	7.53	7.41	8.60	8.03	9.76	8.52	9.15

Table 2: Effect of PROM, sulphur and iron on number of root nodules, fresh and dry weight of root nodules of groundnut (at flowering)

Treatments	Number of root nodules per plant			Weight Of Root Nodules					
				Fresh weight (mg/plant)			Dry weight (mg/plant)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
PROM levels (P)									
P_1: 125 kg/ha	58.83	59.98	59.40	257	263	260	84.75	85.06	84.90
P_2: 250 kg/ha	61.92	63.36	62.64	268	276	272	88.13	92.57	90.35
P_3: 375 kg/ha	63.93	66.02	64.97	276	280	278	92.69	95.79	94.24
S.EM.±	0.955	1.314	0.812	4.63	5.06	3.43	1.813	1.723	1.250
C.D. at 5%	2.71	3.73	2.28	13	14	10	5.14	4.89	3.51
Sulphur levels (S)									
S_1: 12.5 kg/ha	57.65	59.03	58.34	253	258	255	81.89	86.26	84.08
S_2: 25.0 kg/ha	62.60	63.82	63.21	271	275	273	89.48	92.21	90.84
S_3: 37.5 kg/ha	64.43	66.52	65.48	278	286	282	94.20	94.95	94.57
S.EM.±	0.955	1.314	0.812	4.63	5.06	3.43	1.813	1.723	1.250
C.D. at 5%	2.71	3.73	2.28	13	14	10	5.14	4.89	3.51
Iron levels (Fe)									
Fe_1: 2.0 kg/ha	60.48	61.90	61.19	262	269	265	86.65	89.15	87.90
Fe_2: 4.0 kg/ha	61.07	63.16	62.11	267	272	269	88.53	90.99	89.76
Fe_3: 6.0 kg/ha	63.13	64.31	63.72	273	278	275	90.39	93.28	91.84
S.EM.±	0.95	1.31	0.81	4.63	5.06	3.43	1.813	1.723	1.250
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS
Significant interaction	P × S	-	-	-	-	-	-	-	-
CV%	8.06	10.82	9.57	9.02	9.64	9.34	10.64	9.82	10.23

Table 3: Interaction effect of PROM and sulphur on number of root nodules per plant of groundnut (at flowering)

P × S	2022		
	P_1	P_2	P_3
S_1	57.62	58.63	56.70
S_2	58.70	62.32	66.77
S_3	60.16	64.80	68.32
S.EM. ±	1.654		
C.D. at 5%	4.69		

Table 4: Effect of PROM, sulphur and iron on number of pods per plant and filled pods per plant of groundnut

Treatments	Number of pods per plant			Number of filled pods per plant		
	2022	2023	Pooled	2022	2023	Pooled
PROM levels (P)						
P_1: 125 kg/ha	16.81	17.27	17.04	15.15	15.03	15.09
P_2: 250 kg/ha	18.92	18.96	18.94	15.53	16.57	16.05
P_3: 375 kg/ha	19.33	20.02	19.68	16.04	17.13	16.59
S.EM.±	0.304	0.378	0.243	0.247	0.228	0.168
C.D. at 5%	0.86	1.07	0.68	0.70	0.65	0.47
Sulphur levels (S)						
S_1: 12.5 kg/ha	17.08	17.53	17.31	14.59	15.07	14.83
S_2: 25.0 kg/ha	18.64	18.83	18.74	15.90	16.58	16.24
S_3: 37.5 kg/ha	19.34	19.90	19.62	16.23	17.09	16.66
S.EM.±	0.304	0.378	0.243	0.247	0.228	0.168
C.D. at 5%	0.86	1.07	0.68	0.70	0.65	0.47
Iron levels (Fe)						
Fe_1: 2.0 kg/ha	17.63	18.03	17.83	14.97	15.79	15.38
Fe_2: 4.0 kg/ha	18.50	18.71	18.60	15.67	16.30	15.98
Fe_3: 6.0 kg/ha	18.94	19.52	19.23	16.08	16.65	16.37
S.EM.±	0.304	0.378	0.243	0.247	0.228	0.168
C.D. at 5%	0.86	1.07	0.68	0.70	0.65	0.47
Significant interaction	P × S	P × S	P × S	-	-	-
CV%	8.61	10.48	9.61	8.25	7.31	7.77

Table 5: Interaction effect of PROM and sulphur on number of pods per plant of groundnut

P × S	**2022**		
	P_1	P_2	P_3
S_1	16.61	16.92	17.71
S_2	16.93	19.41	19.58
S_3	16.90	20.43	20.69
S.EM. ±	0.527		
C.D. at 5%	1.50		
2023			
S_1	17.06	17.73	17.81
S_2	17.45	18.43	20.61
S_3	17.32	20.72	21.65
S.EM. ±	0.655		
C.D. at 5%	1.86		
Pooled			
S_1	16.83	17.33	17.76
S_2	17.19	18.92	20.10
S_3	17.11	20.58	21.17
S.EM. ±	0.420		
C.D. at 5%	1.18		

Table 6: Effect of PROM, sulphur and iron on pod and haulm yield of groundnut

Treatments	**Pod Yield (Kg/Ha)**			**Haulm Yield (Kg/Ha)**		
	2022	**2023**	**Pooled**	**2022**	**2023**	**Pooled**
PROM levels (P)						
P_1: 125 kg/ha	1908	1998	1953	3105	3296	3200
P_2: 250 kg/ha	2174	2219	2196	3482	3557	3520
P_3: 375 kg/ha	2269	2351	2310	3649	3651	3650
S.EM.±	39.74	48.64	31.41	69.56	68.83	48.93
C.D. at 5%	113	138	88	197	195	137
Sulphur levels (S)						
S_1: 12.5 kg/ha	1854	2001	1927	3055	3341	3198
S_2: 25.0 kg/ha	2195	2225	2210	3498	3550	3524
S_3: 37.5 kg/ha	2302	2343	2322	3683	3612	3648
S.EM.±	39.74	48.64	31.41	69.56	68.83	48.93
C.D. at 5%	113	138	88	197	195	137
Iron levels (Fe)						
Fe_1: 2.0 kg/ha	2010	2103	2056	3266	3397	3332
Fe_2: 4.0 kg/ha	2119	2178	2148	3465	3520	3493
Fe_3: 6.0 kg/ha	2221	2288	2255	3504	3587	3545
S.EM.±	39.74	48.64	31.41	69.56	68.83	48.93
C.D. at 5%	113	138	88	197	NS	137
Significant interaction	P × S	P × S	P × S	P × S	P × S	-
CV%	9.75	11.54	10.72	10.59	10.22	10.40

Table 7: Interaction effect of PROM and sulphur on pod yield (kg/ha) of groundnut

P × S	**2022**		
	P_1	**P_2**	**P_3**
S_1	1806	1844	1911
S_2	1892	2263	2431
S_3	2027	2414	2466
S.EM. ±	68.83		
C.D. at 5%	195		
2023			
S_1	1973	1993	2036
S_2	1982	2288	2406
S_3	2039	2376	2613
S.EM. ±	84.25		
C.D. at 5%	239		
Pooled			
S_1	1890	1919	1973
S_2	1937	2275	2418
S_3	2033	2395	2539
S.EM. ±	54.40		
C.D. at 5%	153		

Table 8: Interaction effect of PROM and sulphur on haulm yield (kg/ha) of groundnut

P × S	2022		
	P_1	P_2	P_3
S_1	2955	3039	3170
S_2	2949	3661	3885
S_3	3411	3747	3892
S.EM. ±	120.5		
C.D. at 5%	342		
2023			
S_1	2882	3528	3613
S_2	3494	3535	3620
S_3	3510	3607	3719
S.EM. ±	119.2		
C.D. at 5%	338		

Additionally, the increase in nitrogen concentration in groundnut may result from enhanced fixation of molecular di-nitrogen by symbiotic bacteria, with sulphur indirectly influencing nitrogen fixation by increasing the number and size of nodules. This interaction between phosphorus and sulphur ultimately raises the protein content in groundnut kernels, a finding supported by Yadav (2011) [38] and Singh *et al.* (2014a) [30].

Conclusion

On the basis of two years experimental findings, it is concluded that application of 375 kg PROM/ha along with 37.5 kg sulphur, 6.0 kg iron and 12.5 kg N/ha (RDN) to groundnut was most effective, leading to increased growth parameters (plant height, root nodules and fresh and dry weight of root nodules), yield attributes (pods per plant, pod and haulm yield), and quality traits (oil and protein content and yield) of groundnut. The findings highlight the importance of balanced nutrient management, emphasizing the combined use of macro- and micronutrients to optimize groundnut productivity and seed quality.

Reference.

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