Effect of Phospho Enriched Compost and Zinc on Productivity and Nutrient Uptake of Blackgram (*Vigna mungo* L.) in Sub-humid Southern Hills and Aravalli Region of Rajasthan

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10.18805/LR-4359

ABSTRACT

Background: Phosphorus (P) and zinc (Zn) are essential plant nutrients and their deficiency in soils has the adverse effect on the crop productivity, moreover the antagonistic effect of P on Zn is also important study aspect. Hence, the present investigation was carried out to study the effect of phospho enriched compost and zinc on productivity, nutrient content and uptake of blackgram (*Vigna mungo* L.) in Sub-humid Southern Hills and Aravalli region of Rajasthan.

Methods: The experiment was undertaken during *Kharif* 2018 at Rajasthan College of Agriculture, Udaipur (Rajasthan). The treatments comprised of four levels of phospho enriched compost (PEC) *i.e.* control, PEC @ 2.0, 4.0 and 6.0 t ha^{-1} and four levels of zinc *i.e.* control, Zn @ 2.0, 4.0 and 6.0 kg ha^{-1}. The experiment was laid out in a factorial randomized block design with three replications.

Result: The increasing levels of phospho enriched compost and zinc upto 4 t ha^{-1} and 4 kg ha^{-1}, respectively increased significantly (P=0.05) the number of nodules per plant, number of pods per plant, number of seeds per pod, test weight, seed yield, stover yield, nutrient content (N, K and Zn) and uptake (N, P, K and Zn) in seed and stover of blackgram. Whereas, the application of zinc significantly decreased the phosphorus content in seed and stover as compared to control. However, the combined application of phospho enriched compost @ 6 t ha^{-1} along with zinc @ 6 kg ha^{-1} was found to record higher seed and stover yield. The application of phospho enriched compost @ 4 t ha^{-1} and zinc @ 4 kg ha^{-1} along with the recommended dose of fertilizer results in significantly higher productivity, nutrient content and uptake of blackgram under Typic Haplustepts soil.

Key words: Blackgram, Content, Phospho enriched compost, Productivity, Uptake, Zinc.

INTRODUCTION

India is the largest producer and consumer of pulses in the world, accounting for about 25 per cent of global production, 27 per cent of consumption and 34 per cent of food use. More than 2/3rd area and production has been obtained from the six states of India *viz*., Madhya Pradesh, Rajasthan, Maharashtra, Karnataka, Andhra Pradesh and Uttar Pradesh (Shukla and Mishra, 2020). Pulses play a significant role in Indian agriculture as they provide protein-rich components in average human diet. They contain 20-24 per cent *i.e*., about 2.5 times more amount of protein than in cereal grains and hence, offers the most practical means of eradicating malnutrition. Blackgram (*Vigna mungo* L.) is one of the important pulses crop in India and it is also a key *Kharif* pulse crop of Rajasthan. In Rajasthan, Blackgram is being grown as a *Kharif* season rainfed crop which occupies an area of 5.40 lakh ha with a production of only 3.37 lakh tones resulting in low productivity around 559 kg ha^{-1} (DAC&FW, 2017-18). The sub-optimal nutrition status and low fertility soils are among the many reasons for low productivity of this crop.

Organic nutrient sources form a very important source of plant nutrients. They supply both macro and micro nutrients to crop plant. Use of organic sources improves the physical, chemical and biological conditions of the soil and helps to maintain and sustain soil fertility and enhance crop productivity in a framework of an ecologically compatible, socially acceptable and economically viable situation. Addition of organic matter into the soil in the form of compost is a feasible strategy to enhance the soil fertility (Zayed and Abdel, 2005). Hence, conversion of agricultural residues into enriched compost by value-addition through cheap minerals like rock phosphate can improve the soil fertility as well as crop productivity. Phospho enriched

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How to cite this article: Meena, M., Jat, G., Meena, R.H., Choudhary, R. Jain, D., Doodhwal, K., Jat, H. and Yadav, S.K. (2022). Effect of Phospho Enriched Compost and Zinc on Productivity and Nutrient Uptake of Blackgram (*Vigna mungo* L.) in Sub-humid Southern Hills and Aravalli Region of Rajasthan. Legume Research. 45(2): 203-208. DOI: 10.18805/LR-4359.

Submitted: 25-02-2020 **Accepted:** 21-10-2020 **Online:** 23-01-2021

compost is considered a valuable organic fertilizer as it supplies nutrients for the crop which results in saving cost of chemical fertilizers (Erhart *et al*., 2005). Besides, it provides all the essential nutrients in readily available forms, enhances uptake of these nutrients by the plants and play a major role in improving growth and yield of crops. Phospho enriched compost also acts as a niche for microbes and enriches the soil with a variety of the indigenous micro-flora and fauna (Paul, 2007).

Most of the soils of Rajasthan which are coarse textured with low to medium organic carbon content and deficient in zinc (Singh and Singh, 1981). Therefore, it becomes necessary to pay serious attention to the application and utilization of zinc. In the coarse texture soil which is low to medium in organic carbon, low moisture retention and microbial activity, the efficiency of native micro-nutrients is further improved when these are used in conjunction with organic manures. This can be attributed to slow decomposition of organic manure and enhanced biological activity of the soil. Micronutrients are essential for the crop production and among the micronutrients, zinc deficiency in the plant and soil has been reported across the world (Alloway, 2008). Zinc is an essential element for the activities of a number of antioxidant enzymes which maintains the membrane lipids, proteins and nucleic acids in plant cells (Cakmak, 2008). In India, zinc is considered as the third important yield limiting nutrient after the nitrogen and phosphorus. As most of the marginal soils brought under cultivation are showing the symptoms of zinc deficiency, it has been predicted that the zinc deficiency in India is likely to increase from 49-63 per cent by the year 2025 (Arunachalam *et al*., 2013). Hence, looking to the above facts the present investigation was carried out to study the effect of the phospho enriched compost and zinc on productivity, nutrient content and uptake by blackgram.

MATERIALS AND METHODS

Experimental site and soil

The experiment was conducted during *Kharif* 2018 at the Instructional Farm (Agronomy), Rajasthan College of Agriculture, Udaipur situated at an altitude of 579.5 meters above mean sea level and at 24°34′ latitude and 73°42′ longitude. The region falls under agro-climatic zone-IVa (Sub- humid Southern Plain and Aravalli Hills) of Rajasthan. The climate of the study area is sub-humid with an average maximum and minimum temperatures during rainy season (July-October) ranged between 27.9 to 34.4°C and the average annual rainfall of 637 mm occurring mostly during the months of July to October. Soil of the experiment was clay loam in texture, alkaline in reaction, medium in organic carbon; low in available N, P, high in available K and low in available zinc (Table 1).

Raw material for phospho enriched compost (PEC)

For the preparation of PEC, four mineral and organic sources *viz*., rock phosphate, mica, maize stover and FYM were used. Rock phosphate and mica were collected from mining sites in Udaipur district of Rajasthan, whereas maize stover and FYM were obtained from the Farm section of Rajasthan College of Agriculture, Udaipur. Before compost preparation the raw materials was analyzed for chemical composition by following the standard laboratory procedures (Table 2).

Preparation of PEC

For the preparation of PEC, 15 kg air dried maize stover chopped in to 5-6 cm size was soaked in water for 24 hours. After soaking, it was mixed thoroughly with required quantities of rock phosphate (RP) and waste mica. To reduce the C:N ratio of maize stover, urea solution @ 0.25 kg N per 100 kg of maize stover and fresh cow dung @ 10 kg per 100 kg of maize stover was added as natural inoculants. Phosphate solubilizing microorganism @ 50 g per 100 kg was also added to maize stover. After that the whole composting mass was mixed thoroughly and put in the cemented pits and covered with jute bag sheets for maintaining moisture. To provide adequate aeration turning was performed after 15, 30 and 60 days of composting and

Table 1: Fertility status of the soil of experimental site.

Properties	Value
pH	8.23±0.16
Electrical conductivity (dS m^{-1})	0.63±0.01
Organic carbon (%)	0.62±0.01
Available N (kg ha^{-1})	272.43±5.45
Available P_2O_5 (kg ha^{-1})	15.85±0.32
Available K_2O (kg ha^{-1})	356.23±7.12
Available Zn (mg kg^{-1})	0.591±0.012

Table 2: Chemical composition of different mineral and organic raw material of PEC.

Nutrient element	Rock phosphate	Mica	Maize stover	FYM
Total C (%)	-	-	45.5±0.7	-
Total N (%)	-	-	0.66±0.01	0.54±0.008
Total P (%)	8.83±0.26	-	0.15±0.002	0.26±0.004
Total K (%)	-	9.57±0.14	1.37±0.021	0.53±0.008
Ca (%)	6.52±0.19	0.12±0.002	-	-
Mg (%)	5.61±0.16	0.051±0.001	-	-
Fe (%)	0.12±0.004	1.08±0.017	185.0±2.87	-
Mn (mg kg^{-1})	664.2±19.50	145.4±2.8	-	-
Cu (mg kg^{-1})	21.7±0.64	15.0±0.3	-	-
Zn (mg kg^{-1})	41.7±1.23	99.2±1.9	23.1±0.36	-

throughout the experiment moisture was maintained to 60% of water holding capacity. For rich nutrient and well decomposed the composting was continued for 120 days.

Chemical analysis of compost and plant samples

The nutrient composition content in raw materials was analyzed by following the procedures of association of official agricultural chemists (AOAC, 1960). The nitrogen content in the compost sample was determined by Macro- Kjeldahl method (Jackson, 1973). Phosphorus, potassium and micronutrients were determined by using 1 g of dry compost sample and digested with tri-acid mixture (HNO_3: $HClO_4$: H_2SO_4 in 9:3:1 ratio) on a hot plate at 180-200°C. Phosphorus extracted solution was estimated by spectrophotometer method (Jackson, 1973), potassium was determined by flame photometer method given by Toth *et al.* (1948) and the micro-nutrient (Zn) was estimated by using atomic absorption spectrophotometer method (Lindsay and Norvell, 1978).The chemical composition of phospho enriched compost used in field experiment is mentioned in Table 3.

Experimental design and treatments

The experiment was laid out in factorial randomized block design and replicated thrice in the plot size of 4.0 m × 3.0 m (12 m^2). The treatments comprised of four levels of PEC *viz.*, control, 2.0, 4.0 and 6.0 t ha^{-1} PEC and four levels of zinc *viz.*, control, 2.0, 4.0 and 6.0 kg ha^{-1} of Zn. The blackgram var. PU-31 was sown in lines of 30 cm apart. As per the treatments, whole quantity of PEC was broadcasted and incorporated into the soil at the time of sowing. The N @20 kg ha^{-1} was applied in two equal splits, the half as basal and the remaining half was top dressed at the time of first irrigation. The basal dose was applied through urea after adjusting the quantity supplied through diammonium phosphate (DAP). The P @40 kg ha^{-1} through DAP and zinc through $ZnSO_4.7H_2O$ were applied as basal and drilled at the depth of 8-10 cm along basal dose of N prior to sowing. The test crop was sown on 7th July 2018 and harvested on 27th September 2018. The seeds obtained from the produce of individual plot were recorded as seed yield kg $plot^{-1}$ and later it was converted into kg ha^{-1}.

Observations recorded

The seed and stover yield was recorded from net plot area of each treatment. The data obtained from various characters under study were analyzed by the method of analysis of variance as described by (Panse and Sukhatme, 1985).

Statistical analysis

The data recorded for different parameters were analyzed with the help of analysis of variance (ANOVA) technique for a factorial randomized block design. The results are presented at 5% level of significance (P=0.05).

RESULTS AND DISCUSSION

Yield

The application of PEC and zinc enhanced the seed and stover yield of blackgram significantly (Table 4). The seed and stover yield was increased significantly up to PEC@ 4 t ha^{-1} which was found to be statistically at par with PEC@ 6 t ha^{-1}. The increase in seed and stover yield was up to the extent of 13.54% & 42.95 % and 15.21% and 29.44% with the application of PEC@ 2 and 4 t ha^{-1}, respectively as compared to control. The significant increase in seed and stover yield under the influence of PEC was largely a function of improved growth and yield attributes which eventually contributed in increased seed and stover yield. The incorporation of PEC in the soil ensures successive and almost continuous supply of macro and micro nutrients to the blackgram over the entire crop growth period (Biswas, 2011). The higher availability of nutrients in soil due to PEC application during seed development might have retarded senescence and resulted in large filling period for greater seed yield. The results corroborate the findings of Meena (2017), attributing the effect of PEC to the release of P from rock phosphate (RP) during decomposition and partially the additive effect of organics. The inter relationship between yields attributes and its seed and stover yield had also been observed by Mali *et al.* (2017), Meena (2017) and Sharma *et al.* (2018).

The seed and stover yield was increased significantly up to zinc @ 4 kg ha^{-1} and remained at par with 6 kg Zn ha^{-1}. The application of 2 and 4 kg Zn ha^{-1} increased the seed yield and stover yield to the extent of 14.37% and 43.21% and 15.26% and 29.46%, respectively as compared to control (Table 4). This might be attributed to increase in yield attributes due to increased supply of available zinc in deficient soil. The significant increase in stover yield due to zinc fertilization could be attributed to the increased plant growth and biomass production, possibly as a result of the uptake of nutrients. These findings are supported by

Table 3: Nutrient contents in phospho enriched compost (PEC).

Nutrient content	Value
N (%)	0.845±0.017
P (%)	1.218±0.024
K (%)	1.159±0.023
Zn (ppm)	35.2±0.7

Table 4: Effect of PEC and zinc on yield of blackgram.

Treatments	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})
PEC levels (t ha^{-1})		
Control	642.96	1175.22
2.0	730.03	1353.96
4.0	919.16	1521.22
6.0	1001.07	1632.77
S.Em±	29.59	43.64
CD (P=0.05)	85.47	126.04
Zinc levels (kg ha^{-1})		
Control	640.76	1174.73
2.0	732.86	1354.09
4.0	917.65	1520.88
6.0	1001.95	1633.49
S.Em±	29.59	43.64
CD (P=0.05)	85.47	126.04

Shanti *et al*. (2008), Khan and Prakash (2014) and Mahilane and Singh (2018) in blackgram crop.

Nutrient content and uptake

The application of increasing levels of PEC and Zn significantly increased the nutrient content and uptake by seed and stover of blackgram. The higher nutrient content (N 3.395 and 1.732%, P 0.428 and 0.261%, K 1.251 and 2.329% and Zn 10.83 and 21.01 mg kg^{-1}) and uptake (N 34.24 and 28.47 kg ha^{-1}, P 4.26 and 4.25 kg ha^{-1}, K 12.63 and 38.25 kg ha^{-1} and Zn 109.27 and 344.96 g ha^{-1}) in seed and stover was obtained under the treatment PEC_3 (Phospho enriched compost @ 6 t ha^{-1}) and the minimum under control (PEC_0), respectively (Tables 5 and 6). The increase in nutrient uptake due to application of 4 t phospho enriched compost ha^{-1} were in order of N 60.42 and 50.11%, P 63.32 and 51.42%, K 67.46 and 51.51% and Zn 53.47 and 45.56% in seed and stover of blackgram, respectively as compared to control (PEC_0). However, the nutrient uptake of N and K in seed and stover was increased significantly up to PEC@ 4 t ha^{-1} which was found to be statistically at par with PEC@ 6 t ha^{-1}. The positive influence of phospho enriched compost was due to adequate supply of nutrients in root zone and plant system. The increased availability of these nutrients in the root zone coupled with increased metabolic activity at cellular levels might have synthesized more nutrients and their accumulation in various plant parts (Biswas, 2011). The increased uptake of nitrogen, phosphorus and potassium content in seed and stover seems to be due to the fact that uptake of nutrient is a product of biomass and nutrient content. The nutrient accumulation in plant is dependent on dry matter accumulation in plant and concentration of nutrient at cellular level. It is evident form significant correlation between dry matter accumulation and uptake of nutrients. The results obtained in the present investigation are in close conformity with those of Biswas (2011) and Mali *et al*. (2017). The increase in content of Zn with application of phospho enriched compost might be due to increased availability of native micronutrient cations. Thus, positive effects of phospho enriched compost on nutrient availability and their extraction due to increase activity of roots ultimately improved the nutrient status of the plant parts (Nimje and Potkitc, 1997). This is due to transformation of their solid phase form to soluble metalo-complexes and the application of micro-nutrients increased their contents (Biswas, 2011).

The maximum nutrient content (N 3.396 and 1.742%, K 1.250 and 2.275% and Zn 10.93 and 21.01 mg kg^{-1}) and uptake (N 34.32 and 28.69 kg ha^{-1}, P 3.85 and 3.69 kg ha^{-1}, K 12.67 and 37.49 kg ha^{-1} and Zn 110.39 and 345.55 g ha^{-1}) in seed and stover was recorded under the treatment Zn_3 (Zinc @ 6 kg ha^{-1}) as compared to control (Zn_0), respectively. Whereas, the application of zinc significantly decreased the phosphorus content in seed and stover as compared to control. The increase in nutrient uptake due to application of 4 kg Zn ha^{-1} were in order of N 58.88 and 49.25%, P 34.46 and 20.47%, K 66.22 and 39.09% and Zn 59.86 and 45.84% in seed and stover of blackgram, respectively as compared to control (Zn_0) (Tables 5 and 6). It is might be due to the synergistic interaction between zinc and nitrogen, potassium many zinc dependent enzymes are involved in carbohydrate metabolism in general and leaves in particular, impartment of K in stomata regulation, phloem export of assimilation from the source *i.e*. the leaves into the sink organs, maintained water balance in the soil-plant atmosphere continuum. The nitrogen content and uptake in seed and stover could be due to zinc application since zinc is essential for synthesis of DNA and RNA and for metabolism for the production of carbohydrate, lipids and proteins. These resulted support the findings of Keram *et al*. (2012) who stated that the increase could be attributed to the synergistic effect between N and Zn which might be due to increase enzymatic activity by zinc application. The increase in potassium content and uptake due to interaction of K and zinc by the improvement of enzymatic activity and metabolic processes of plant which might has ultimately facilitated the removal of potassium and consequently the yield. The results obtained get support from the finding of Shivay *et al*. (2015).

Table 5: Effect of phospho enriched compost and zinc on nitrogen, phosphorus, potassium and zinc content in seed and stover of blackgram.

Treatments	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Zinc (mg kg^{-1})	
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
PEC levels (t ha^{-1})								
Control	2.894	1.447	0.361	0.211	1.016	1.946	9.61	17.79
2.0	3.179	1.540	0.392	0.232	1.181	2.119	10.01	19.48
4.0	3.287	1.704	0.409	0.247	1.214	2.298	10.47	20.22
6.0	3.395	1.732	0.428	0.261	1.251	2.329	10.83	21.01
S.Em±	0.057	0.031	0.006	0.003	0.019	0.027	0.135	0.257
CD (P=0.05)	0.164	0.091	0.017	0.008	0.054	0.078	0.389	0.741
Zinc levels (kg ha^{-1})								
Control	2.888	1.445	0.419	0.251	1.017	2.044	9.36	17.76
2.0	3.177	1.539	0.401	0.243	1.183	2.128	10.08	19.50
4.0	3.295	1.697	0.390	0.235	1.212	2.245	10.55	20.24
6.0	3.396	1.742	0.379	0.223	1.250	2.275	10.93	21.01
S.Em±	0.057	0.031	0.006	0.003	0.019	0.027	0.135	0.257
CD (P=0.05)	0.164	0.091	0.017	0.008	0.054	0.078	0.389	0.741

Table 6: Effect of phospho enriched compost and zinc on nitrogen, phosphorus, potassium and zinc uptake by seed and stover of blackgram.

Treatments	Nitrogen (kg ha^{-1})		Phosphorus (kg ha^{-1})		Potassium (kg ha^{-1})		Zinc (g ha^{-1})	
	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover
PEC levels (t ha^{-1})								
Control	19.00	17.40	2.29	2.47	6.73	23.18	63.18	212.54
2.0	23.46	20.94	2.84	3.12	8.72	28.84	73.60	265.12
4.0	30.48	26.12	3.74	3.74	11.27	35.12	96.96	309.37
6.0	34.24	28.47	4.26	4.25	12.63	38.25	109.27	344.96
S.Em±	0.973	0.826	0.124	0.115	0.386	1.100	3.355	9.40
CD (P=0.05)	2.811	2.385	0.358	0.333	1.115	3.178	9.690	27.15
Zinc levels (kg ha^{-1})								
Control	19.14	17.40	2.67	2.98	6.75	24.71	60.93	211.83
2.0	23.33	20.87	3.03	3.31	8.72	28.82	74.29	265.66
4.0	30.41	25.97	3.59	3.59	11.22	34.37	97.40	308.94
6.0	34.32	28.69	3.85	3.69	12.67	37.49	110.39	345.55
S.Em±	0.973	0.826	0.124	0.115	0.386	1.100	3.355	9.40
CD (P=0.05)	2.811	2.385	0.358	0.333	1.115	3.178	9.690	27.15

Table 7: Interactive effect of PEC and zinc on seed yield (kg ha^{-1}) of blackgram.

Treatments	Control	PEC @ 2.0 t ha^{-1}	PEC @ 4.0 t ha^{-1}	PEC @ 6.0 t ha^{-1}
Control	1170.47	1653.97	2309.28	2555.37
Zn @ 2.0 kg ha^{-1}	1747.31	2028.40	2386.52	2632.15
Zn @ 4.0 kg ha^{-1}	2328.60	2401.27	3018.17	3263.76
Zn @ 6.0 kg ha^{-1}	2469.09	2676.75	3315.97	3561.60
S.Em±	59.18			
CD (P=0.05)	170.94			

Table 8: Interactive effect of PEC and zinc levels on stover yield (kg ha^{-1}) of blackgram.

Treatments	Control	PEC @ 2.0 t ha^{-1}	PEC @ 4.0 t ha^{-1}	PEC @ 6.0 t ha^{-1}
Control	2481.04	3340.33	3969.91	4305.43
Zn @ 2.0 kg ha^{-1}	3456.05	4021.13	4218.73	4553.12
Zn @ 4.0 kg ha^{-1}	3995.58	4257.73	4831.47	5165.79
Zn @ 6.0 kg ha^{-1}	4170.02	4628.37	5234.55	5568.94
S.Em±	87.28			
CD (P=0.05)	252.08			

Whereas, phosphorus content in seed and straw of blackgram decreased with increasing level of zinc. It might be due to the antagonistic effect of zinc on phosphorus absorption. Zinc was found to inhibit the translocation of phosphorus from root to top. The results are in agreement with the results obtained by Dewal and Pareek (2004). The significant increase in the phosphorus uptake in seed and stover was probably due to increase in seed and stover yield of black gram. The increase in zinc content and uptake in seed and stover at harvest might be due to the presence of increased amount of zinc in soil solution by the application of zinc that might have facilitated the absorption of zinc through phloem. The results obtained get support from the findings of Todawat *et al.* (2017) and Ranpariya and Polara (2018).

Interaction effect of PEC and zinc on seed yield and stover yield

A significant interactive effect of PEC and zinc on seed yield and stover yield of blackgram (Tables 7 and 8) ware observed. Although all the combinations of PEC and Zinc levels recorded significantly higher yield over control. However, the significantly maximum seed yield (3561.60 kg ha^{-1}) and stover yield (5568.94 kg ha^{-1}) was obtained under PEC @ 6 t ha^{-1} and Zn @ 6 kg ha^{-1} combination and the lowest under control. The increase in seed yield and stover yield might be due to the fact that PEC and zinc had an additive effect. Since the experimental soil was deficient in nutrients especially Zn the supplementation of Zn with PEC incorporation improved the availability of both nutrients as well as water by increased water and nutrient retention in the root zone by reducing infiltration and percolation. These findings are in agreement with those of Sharma *et al.* (2015) on mustard and Todawat *et al.* (2017) on greengram.

CONCLUSION

On the basis of experimental finding, it can be concluded that the application of phospho enriched compost @ 6 t ha^{-1}

+ zinc @ 6 kg ha^{-1} along with the recommended dose of fertilizer results in significantly higher productivity and nutrient uptake by blackgram under Typic Haplustepts soil of Sub-Humid Southern Hills and Aravalli Region of Rajasthan.

ACKNOWLEDGEMENT

The corresponding author thankful to the Principal Investigator, RKVY Project for providing necessary facilities for conducting this study.

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