

Physico-bio-chemical Properties of Sandy Soil Conditioned with Acrylamide Hydrogels after Cucumber Plantation

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Abstract: A two successive years completely randomized field experiment with drip irrigated cucumber (*Cucumis Sativus L. Var. Madina*) was conducted at El-katta, Giza Governorate to study the changes in some physico-bio-chemical properties of a virgin sandy soil after treating with hydrophilic polymers and plantation. The hydrogel used was a mixture of an anionic “ polyacrylamide K polyacrylate 30% anionicity and a cationic “ polyacrylamide allylamine hydrochloride 20 % cationity “ hydrogels at the ratio of 2:3. Examined application rates of the hydrogel were 2, 3 and 4 g/plant pit. At the end of the growing season some physico-bio-chemical properties of the soil were determined. Obtained results could be summarized as follows: 1-Applied conditioner positively affects hydrophysical properties of soil. These include a- improving soil structure expressed by water stable structural units > 0.25 mm in diameter, and structure coefficient, dry stable structural units > 0.84 mm in diameter and wind erosion parameter indicating high resistance of the soil against both wind and water erosion and the destruction of the soil by tillage operations. b-decreasing soil bulk density as well as macro porosity (drainable pores) on the expense of micro ones. Therefore, water holding pores were increased. c- increasing retained moisture in the soil at all suctions under study (from 0 to 15 bars.). Since the increase in water retained in the soil at field capacity is far beyond that at wilting percentages, available water was highly increased d- decreasing mean diameter of soil pores and in turn its water transmitting properties namely: infiltration rate, hydraulic conductivity and transmissivity for vertical flow of water through soil profile. Evaporation was also decreased. 2-Soil conditioning positively affect chemical and biological properties of the soil. These effects are assembled in the following: a-slightly decrease soil pH. b- increasing both CEC of the soil and its specific surface area indicating an improvement in activating chemical reactions in the soil. c- increasing OM, organic carbon and total nitrogen in the soil. Because the increase in organic nitrogen is higher than that in organic carbon, narrower C/N ratio of treated soil was obtained indicating the mineralization of organic nitrogen compounds and hence the possibility to save and provide available forms of N to growing plants. d- increasing N, P and K in treated soil. e- improving the biological activity expressed as total count of bacteria, i.e Azotobacter sp, and PDB, fungi and actinomycetes in the soil and the activity of both dehydrogenase and phosphatase. 3- In all cases, improvements in soil properties are positively affected by the application rate of the conditioners.

Keywords: Acrylamide hydrogels, Sandy soil, soil conditioning, Physico-bio-chemical properties

INTRODUCTION

Sandy soils have two major problems: i.e low fertility and inadequate water retention. Wind erosion, water erosion, drought and loss of irrigation water and plant nutrients are expected. However, they could be as productive as any fertile soil, if the right soil water management practices are followed. Other than adding clays or organic manures and composts to sands, the only obvious way to keep moisture more available in such soils is frequent water application and / or the use of synthesized soil conditioners. Although clays (100 to 150 m³ / fed.) could be mixed with sand to improve its water retentivity, such treatment is expensive. It is usually justified only when land is very limited. The application of organic materials to sandy soils (10 to 20 ton/fed), has quite a similar effect to that of clay with some exceptions that organic matter is usually decomposed too fast that it is difficult to maintain more than 1 or 2 percent without heavy and seasonal manuring.

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Frequent irrigation is the usual solution for keeping enough water available in sandy soils. The high porosity of sands will allow excessive losses of water and dissolved fertilizers especially if overland flow methods of watering are used, (El-Hady *et al* 2003).

The use of synthesized conditioners to avail suitable environment for planting sandy soils under the severe conditions of our deserts i.e the limited water resources; the inadequate water retention and low fertility of the soils – has become an accepted practice. Among these conditioners are hydrogels. Hydrogels. (Super absorbent materials) are hydrophilic polymeric products that associate quickly with irrigation water to form gels. When mixed with sandy soil, they increase its capacity to retain water. Water retained in this way is available to plants for some considerable time, as required. Due to the bending effects of hydrogels molecules with sand particles and their swellability, an improved structure of the sandy soil is obtained, besides, beneficial changes in soil porosity, particularly the amount of water retaining pores. Both chemical and biological properties of the conditioned soils are also improved. Moreover, germination process, plant growth, nutrients uptake, yield and both water and fertilizers use efficiency by plants were beneficially increased by mixing the plant pits in sandy soil with hydrogels, (Ouchi *et al*, 1990; Nus, 1992; Smagin and Sadovrikova, 1995; Nadlear *et al*, 1996; El-Hady *et al*, 2001, 2002, 2003).

The aim of the present work is to study the impact of hydrophilic conditioners (hydrogels) on some physico-bio- chemical properties of sandy soils. A field experiment with trickle irrigated cucumber (*cucumis Sativus*, L.) Was conducted at El-Katta, Giza Governorate (El-Hady and Wanns 2006). A virgin sandy soil was treated with a polyacrylamide hydrogel at different application rates. At the end of the growth season some some physico-bio- chemical properties of the soil, were determined.

MATERIALS AND METHODS

A completely randomized field experiment with four replications for each treatment was conducted on a virgin sandy soil (sand % = 92.0 %, pH = 7.8 , EC =1.1 dSm⁻¹ CaCO₃ =6.2 % and O.M = 0.1%) at El-Katta Giza Governorate, Trickle irrigated cucumber (*cucumis Sativus L. var Madina*) was chosen as the indicator plant. The main analytical data of the soil and irrigation water were presented else where (El-Hady and Wanns 2006) . The soil was treated with mixture of an anionic polyacrylamide K acrylate 30% anionicity and a cationic “ polyacrylamide allylamine hydrochloride 20 % cationicity “ hydrogels at the ratio of 2:3 (G0), (Table. 1) at 3 application rates i.e. 2, 3 and 4 g / plant pit (about 2 kg soil).

Table 1: Description of the main constituents and properties of hydro gels used.

a-Main constituents		
Ionicity	Anionic	Cationic
Active substance	Propeneamide Propionic acid Co-polymer (K -salt)	Propeneamide Allylamine Co-polymer (CL- salt)
Ionization degree	30 mole%	20 mole%
Cross linker		Divalent vinyl monomer
Cross-inking ratio		1:10 ⁻⁴ mole/mole
Percentage of active substance		Greater than 88%
Monomer content Not higher than 300 ppm		
b-Properties:		
Appearance:	white to slightly yellow grains	
Grain size:	0.25 -1 mm	
Bulk density	≈ 600 kg/m ³	
Solubility	Insoluble in water and organic solvents	
pH 0.1% in distilled water	7 ±0.5	
CEC C mole kg ⁻¹	2045	2175
Absorption capacity in g/g hydrogel		
De ionized water	≈ 525	≈ 430
0.9 % NaCl	≈44	≈ 35
0.4% CaCl ₂	≈41	≈36
Saline water (1500 ppm)	≈ 64	≈54
Absorption time:		
Up to 50 %	20 minutes	
Total absorption	60 minutes	

The conditioning effects on some physico-bio-chemical properties of the soil either conditioned or not were determined at the end of the growth season, i.e after 105 days from plantation as follows:

Physical properties: Soil physical properties were determined according to (Dewis and Freitas, 1970; Hillel, 1971; Loveday, 1974; El-Shafei and Ragab, 1976; El-Hady, 1984; and El-Hady and El-Sherif, 1988). The studied parameters are: a) water stable structural units > 0.25 mm in diameter and structure coefficient, b) dry stable structural units > 0.84 mm in diameter and wind erosion parameter; c) Soil bulk density, total porosity and pore size distribution; d) water retention at different suctions and available moisture; e) infiltration rate, hydraulic conductivity, transmissivity for vertical flow through the soil profile; f) adjusted evaporation; g) surface area was estimated calorimetrically using othophenanthroline adsorption method (Lowrie, 1961).

Chemical Properties:

The following determinations were carried out according to (Cottenie *et al.*, 1982). a) Soil pH was determined in 1 : 2.5 soil water suspension; b) Electrical conductivity (dSm⁻¹) of the soil paste extract; c) Organic matter content; d) Total, organic and available N; e) Total and available P; g) Total and available K

Biological Properties:

Microbial Parameters:

a) Total bacterial content was determined using nutrient agar medium (Difco, 1966); b) Azotobacter count was determined using Ashb's medium (Allen, 1953); c) Phosphate dissolving bacteria content (PDB) was determined using (Bunt&Rovira, 1955) modified by Abd El-Hafez (1966); d) Actinomycetes count were determined using glycerol nitrate agar medium (Szabo, 1974); e) Total fungal count was determined using Martins medium as described by (Marten, 1950).

Enzymatic activity:

a) Dehydrogenase enzymes were determined after (Skujins,1973) b) Phosphatase enzymes were determined after (Katai *et al*, 1986).

RESULTS AND DISCUSSIONS

Effect on Hydro-physical Properties:

Some hydro-physical properties of the soil i.e. structure stability, porosity and pore size distribution, moisture retention and transmissivity as influenced by conditioning the soil are presented in Table 2.

Table 2: Effect of the acrylamide hydrogel on some hydrophysical properties of the soil.

Application rate											
g/plant pit	%	Water stable structural units > 0.25 mm (%)	Structure coefficient (Cr)	Dry stable structural units > 0.84 mm (%)	Wind erosion parameter	Bulk density (kgm ⁻³)	Total porosity (%)	Macro pores (drainable pores >28.8µ) *	Micro pores < 28.8µ) *		Macro: micro
									Water holding pores (28.8-0.19µ)	Fine capillary pores (<0.19 µ)	
0	0	17.25	0.208	12.0	1.0	1.615	39.06	78.6	15.1	6.3	0.272
2	0.10	24.15	0.318	23.1	0.519	1.595	39.81	64.6	29.0	6.4	0.548
3	0.15	36.65	0.579	32.6	0.368	1.575	40.57	56.9	36.7	6.4	0.757
4	0.20	45.75	0.843	37.8	0.317	1.550	41.15	50.1	43.5	6.4	0.996
g/plant pit	%	Water holding capacity (WHC) (%)**	Field Capacity (FC) (%)**	Wilting percentage (WP)**	Available moisture (%)**	Infiltration rate of air dry soil cm.h-1	Hydraulic conductivity (m.day-1)	Mean diameter of soil pores (µ)	Tranmissivity (ΣK/D) day-1	Adjusted evaporation (E. adj.)	
0	0	20.15	6.15	1.33	4.82	60.8	12.0	21.4	114.3	1.00	
2	0.10	23.05	9.10	1.40	7.70	44.1	7.3	16.7	81.8	0.83	
3	0.15	27.10	12.05	1.43	10.62	37.6	5.6	14.6	70.5	0.67	
4	0.20	33.75	13.95	1.48	12.47	31.4	4.8	13.5	65.1	0.58	

* As a % of total porosity ** on dry weight basis

Wet sieve analysis was used to determine the percent of water stable fraction > 0.25 mm in diameter and this fraction was taken as a reflection of soil aggregate stability (El-Hady and El-Sherif, 1988). Data show that addition of the examined hydrogel resulted in an increase in water stable structural units > 0.25 mm in diameter being higher with increasing the application rate. Increments in this fraction were 40.0, 112.5 and 165.2 % over that of untreated soil for the treatments 2, 3 and 4 g hydrogel/plant pit, respectively.

In order to find out the aggregating capacity and to compare quantitatively between the different treatments, structure coefficient (Cr) as suggested by El-Shafei and Ragab (1976) was calculated. This coefficient is the ratio of the percentage content of the total amount of fractions greater than 0.25 mm in diameter to the percentage content of fractions having the diameter less than 0.25 mm. Values of calculated

(Cr) reveal a marked increase in (Cr) as a result of applying the hydrogels to sandy soil. Using 2,3 and 4 g of the hydrogel / plant pit (about 2 kg soil) raised this index to be 1.52, 2.78 and 4.05 times as that of the untreated sandy soil, respectively. It is well known that the higher this index is, the more stable is the soil structure.

Dry stable structural unit >0.84 mm in diameter are used as criteria to evaluate soil mechanical stability and the resistance of the structural units of sandy soil against breakdown by tillage or by wind erosion (El-Hady, 1984). Incorporating 2 or 3 g of examined hydrogel in the plant pit of sandy soil nearly doubled or trebled the percentages of structural units > 0.84 mm in diameter. This index reached 3.15 times that of untreated soil after incorporating 4 g of the hydrogel in the plant pit. Wind erosion parameter was calculated as the ratio between the percentages content of the structural units > 0.84 in diameter of the untreated soil and these of treated ones. The lower the calculated parameter is, the more stable is the soil (El-Hady and El-Sherif, 1988) . Data reveal that soil structure was improved by soil conditioning. Incorporating the hydrogel in sandy soil reduced this parameter by 48.1; 63.2 and 68.3 % with 2,3 and 4 g hydrogel/ plant pit, respectively.

Values of soil bulk density, soil porosity and macro and micro – porosity as influenced by treating sandy soil with the hydrophilic conditioners reveal that soil conditioning decrease the bulk density of the soil as well as the macro – porosity (drainable pores having the diameter of $> 28.8 \mu$) relative to those of untreated soil, noteworthy that the macro porosity was taken as the air – filled porosity when the soil water system was in equilibrium with 100 cm suction (Loveday, 1974). This decrease was calculated to be 1.2 , 2.5 and 4.0 % for the bulk density and 17.8; 27.6 and 36.3 % for the macro porosity due to the application of 2, 3 and 4 g hydrogel to the plant pit of sandy soil, respectively.

In regard to the effect of added conditioners on total porosity and micro porosity, especially those which hold available moisture to plants, i.e., water holding pores having the diameters of 28.8 to 0.19μ , the data took an opposite trend to that of bulk density and macro porosity. On other words, the increase relative to these of the control that reached 1.9, 3.9 and 5.4 % in total porosity and 92.1, 143.0 and 188.1 % in water holding pores were obtained in soil when conditioned with 2, 3 and 4 g hydrogel / plant pit, respectively. The ratio between micro and macro pores is of great importance in revealing the rate of water retention and water movement in the soil. It is interesting to note that incorporating the examined hydrogels into sandy soil beneficially modify this ratio. While micro : macro porosity in the untreated soil was 0.27 : 1 , it increased by soil conditioning to be 0.55:1 and 0.76 :1 due to the addition of 2 and 3 g hydrogel / plant pit respectively and to reach about 1:1 by addition of 4 g hydrogel to each plant pit of sandy soil indicating slow water movement and more water retention in the soil as will be presented later.

Retained moisture in sandy soil under different suctions from zero to 15 bars as influenced by soil conditioning is also shown in Table 2. Data in hand refer to an increase in the percentages of retained moisture at all suctions under study due to soil conditioning being higher with increasing the application rate of the conditioner. At saturation , i.e. at $pF=0$ the total water holding capacity (WHC) of the soil was increased by 14.4 , 34.5 and 67.5 % when incorporating 2, 3 and 4 g of the hydrogel in the plant/ pit, respectively. At field capacity (FC), i.e. at $pF= 2.0$ values of retained moisture show an increase of 48.0, 95.9 and 126.8 % relative to that of the control by applying the same rates of the hydrogel mentioned above, respectively. Since the increase in water retained at FC is far beyond that at wilting percentage (WP), i.e., at $pF= 4.2$, the available water (FC-WP) increased. Incorporating 2, 3 and 4 g of applied hydrogel in the soil of the plant pit raised its available moisture to be 1.60, 2.20 and 2.59 times that of untreated soil, in sequence. Obtained results could be explained on the basis of increasing the smaller pores having the diameter of $28.8 - 0.19 \mu$ on the expense of the large ones, i.e., drainable pores having the diameter of $> 28.8 \mu$. Moreover, the higher the application rate of the conditioner is, the lower in the macro-pores in the soil. As previously mentioned, the increase of water storage pores is vital to ensure water reservation in sandy soil under dry farming conditions. It is well known that increasing available moisture for plant elongates irrigation frequencies and in turn decreases the quantities of irrigation water needed and costs of irrigation process. (El-Hady and Wanas, 2006).

Alternation of water transmitting properties of sandy soil, i.e. the rapid loss of water by either deep percolation or evaporation, is one of the major objectives of applying soil conditioners to such soils. Some water transmitting properties of the soil under study as influenced by treating with the examined hydrogel are also presented in Table 2. These properties include the infiltration rate of air dry soil (cm h^{-1}), the minimum hydraulic conductivity (m day^{-1}) of 2-4 mm fractions after percolation for three hours under a constant water head, mean diameter of soil pores (μ), transmissivity for vertical flow of water through soil profile ($\sum K/D\text{day}^{-1}$) and adjusted evaporation (Eadj.). Data in hand show that incorporating the examined hydrogel in sandy soil decreased the values of all studied properties, being lower with the application rate of the conditioner. With

this respect, the decrease in water transmitting properties of sandy soil due to the addition of 2 g hydrogel / plant pit reached 27.5, 39.2, 22.0, 28.4 and 17.0% that of untreated sandy soil for the infiltration rate, hydraulic conductivity, mean diameter of soil pores, transmissivity for vertical flow of water and adjusted evaporation, respectively. With 3 g hydrogel/plant pit these decrease were 38.2, 53.3, 31.8, 38.3 and 33.0 % that of untreated sandy soil for the aforementioned properties, in sequence. Relevant values for 4 g hydrogel / plant pit treatment were 48.4, 60.0, 36.9, 43.0 and 42.0 %, respectively .

The explanation for the better changes in the water transmitting properties of sandy soil with conditioning could be attributed to the increase in soil micro porosity as previously mentioned and in turn, the increase in the hydraulic resistivity of the treated sandy soil.

Effect on Chemical Properties:

Data presented in Table (3) reveal that some chemical properties of studied soil were improved by varying degrees due to soil conditioning.

Table 3: Effect of acrylamide hydrogel on some chemical properties of the soil

Application rate	pH	OM	CEC	Specific	Available macronutrients			P	K	Total	Organic	
-----	1:2.5	%	C mole	Surface	-----			Mg/kg	Mg/kg	N	C	
g/plant	%*	H ₂ O	Kg ⁻¹	Area m ² /g	N (mg/kg soil)			soil	soil	µgg ⁻¹	µgg ⁻¹	
pit*	(w/w)				NH ⁴⁺	NO ⁻³	NH ⁴⁺					
							NO ⁻³					
0	0	7.80	0.11	4.75	10.1	13.2	25.4	38.6	25.1	198.1	60	638
2	0.10	7.35	0.39	8.23	16.3	16.0	43.2	59.2	46.3	290.6	400	2262
3	0.15	7.30	0.46	9.15	18.2	16.9	50.8	67.7	59.4	305.5	480	2668
4	0.20	7.25	0.50	10.25	19.8	17.8	56.6	74.4	70.7	341.4	530	2900

*plant pit ≈ 2 kg

Regarding soil pH, all examined conditioning treatments slightly decreased the PH values of the soil. The decrease was calculated to be 0.45, 0.50 and 0.55 units using 2, 3 and 4g G / plant pit as soil conditioner respectively. One of the important limitations of soil fertility of sandy soils is its low CEC and subsequently its low specific surface area since many soil properties such as adsorption of water, nutrients and even gases and the attraction forces between particles are all surface phenomenon. Treating the soil with G raises such parameters. Cation Exchange Capacity or specific surface area of treated soil was 1.73, 1.93 and 2.16 times or 1.61, 1.80 and 1.96 times with 2, 3 and 4 g G /plant pit respectively. It seems that CEC and surface area of treated soils coincide with the CEC of applied conditioner and its application rates. With respect to soil organic matter % and accordingly its organic carbon content, treating the soil with examined hydrogel 2, 3 and 4 g G /plant pit raise both soil parameters being higher with the rate of applied conditioner. In other words using 2, 3 and 4 g G / plant pit increased organic matter and organic carbon content of the soil to be 3.6, 4.2 and 4.6 times that of un-treated soil, respectively. Similarly, total nitrogen and organic nitrogen content took the same trend of organic matter % and organic carbon content. Compared with the control treatment, values of total N were highly increased to be 6.7, 8.0 and 8.8 times with 2, 3 and 4 g of applied hydrogel to the plant pit. Relevant values for organic N were 15.9, 19.3 and 21.3 times, in sequence. Because the increase in organic carbon is far beyond that of total nitrogen, carbon nitrogen ratios are much narrower. Carbon:Nitrogen of untreated sandy soil was 29.8 :1. By treating the plant pit with 2, 3 and 4 g G, values of C: N ratio were 6.6: 1, 6.47 :1 and 6.37:1 respectively . Such decrease in C: N refers to the easiness of the mineralization of organic nitrogen compounds, and the possibility to save and provide available forms of N to growing plants.

It is well known that availability of nutrients in untreated sandy soil is low. Under the conditions of conducted experiment, and although fertilization is the same as that of other treatments , available N, P and K were 38.6, 25.1 and 198.1 mg/kg soil, respectively , that refer to poor nutritional status of the soil. Considerable increases in the availability of studied nutrients were noticed due to soil conditioning. Using 2% OM the availability of studied nutrients was noticed due to soil conditioning. Applying the three rates of G for soil conditioning (i.e. 2, 3 and 4 g G / plant pit), increase the availability of the aforementioned nutrients to be 53.4, 75.4 and 92.7 % for N; 84.5, 136.7 and 181.7% for P and 46.7, 54.2 and 72.3% for K consequently over control.

Effect on Biological Properties:

Data presented in Table (4) reveal that some biological properties of the studied soil were improved by varying degrees due to soil conditioning.

Table 4: Effect of acrylamide hydrogels on some biological properties of the soil

Application rate	Total bacteria	Azotopacter	Phosphate dissolving bacteria	Total Fungai	Total action-Mycetes X	Activity of dehydrogenase*	Activity of phosphatase***
g/plant pit	% (w/w)	X10 ⁶ /g	X10 ⁴ /g	X10 ⁴ /g	10 ⁴ /g		
0	0	14	20.5	15.1	18.6	5	21.1
2	0.1	33	24.9	26.6	21.8	16.3	28.2
3	0.15	35	26.6	26.2	24.3	18.3	33.4
4	0.2	36	28.2	36.4	26.7	20.2	36.7

* plant pit \approx 2 kg** m⁻²/H₂/g dry soil /24 h.*** mg /P₂O₅ /100 g soil /24h.

Micro-organisms such as bacteria, fungi and actinomycetes influence profoundly the physical, chemical and especially the biological properties of soils. Activities of such organisms include the decomposition of plant residues and other organic materials and the formation of humus, the most chemically and physically active group of compounds in the soil. One result of these processes of decay is the release from organic forms of essential plant nutrients, such as nitrogen, phosphorus and sulfur. Subsequently, still other micro-organisms can oxidize, reduce and otherwise changes the state of the nutrients elements in the soil.

These changes have profound influence on plant growth and otherwise affect soil properties in addition to the role of organic fertilizers as amendment for improving physical and chemical characteristics of the soil, which in turn reflected on rhizosphere microflora, plant growth and yield (Brady, 1990; El-Hady and Abo-sedera, 2006). As increasing the low number of micro-organisms mentioned above i.e bacteria, fungi and actinomycetes in sandy soil indicates an improvement in its biological fertility, data presented in Table (4) refer to such improvement due to soil conditioning. While applying 2 g G to the plant pit increased the number of total bacteria *azotobacter sp.*, phosphate dissolving bacteria (PDB), fungi and actinomycetes by 136, 22, 76, 17 and 30%, in sequence. Such increase was 157, 38, 108, 44 and 72 %, respectively when the rate of G was doubled to be 4 g / plant pit.

Since most of the biological reactions in the soil are enzymatic changes, enzymes activity could be considered as another parameters to characterize the biological activity of the soil. With this respect both dehydrogenase and phosphatase activities were essayed. Increases in enzymes activity due to applying 2, 3 and 4 g G /plant pit were 234, 266 and 304% for dehydrogenase and 34, 58 and 74 for phosphatase activities, in sequence.

Obtained results coincide with those of other investigators (Ouchi *et al* 1990, Smagin and Sadovrikova, 1995; Nadler *et al* 1996; El-Hady *et al*, 2002 and 2003; and El-Hady and Abo –sedera 2006), and indicate the importance of applying such hydrophilic conditioners to sandy soils to improve their physico- bio- chemical properties and in turn their potentialities to produce economic yields.

Due to the effect of salinity on decreasing the efficiency of hydrogels, (El-Hady, 1993; El-Hady & Abd El-Hady, 1997); It is recommended to apply diluted fertilizer solutions to growing plants through the irrigation system. Organic materials to be incorporated into the soil must be free of salts if possible. The lower the salt content of treated soil and irrigation water is the higher is the efficiency of applied hydrogel.

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